THE EFFECT OF TEACHING-LEARNING STRATEGIES ON THE ENHANCEMENT OF ACADEMIC ACHIEVEMENT IN GRADE 9 SCIENCE

by

ELIZABETH ANNE JORDAN

86-02598/

Report No. 86:04

THE EFFECT OF TEACHING-LEARNING STRATEGIES ON THE ENHANCEMENT OF ACADEMIC ACHIEVEMENT IN GRADE 9 SCIENCE

GRANT NUMBER: DG 361

AUTHOR(S): Elizabeth Jordan

PROJECT SITE
OR SAMPLE ____________________

This report is based on a study or project funded by the ERIBC Grants Program. This report may be reproduced in whole or in part, but the author(s) and ERIBC must be credited.

ERIBC takes no responsibility for the work as it was carried out, or the conclusions drawn by the author(s).

EDUCATIONAL RESEARCH INSTITUTE OF B.C.

Suite 701 - 601 West Broadway

Vancouver, B.C. V5Z 4C2

Telephone: (604) 873-3801

ABSTRACT

Using Information-Processing as a theoretical base this study sought to determine whether or not specific cognitive strategies could be taught and learned. These strategies dealt with memory skills which have been shown to occur naturally in mature learners. However, it has been shown that even some university students lack these basic skills and resort to ineffective memory techniques. This results in failure to recall information and an inability to resolve problem solving tasks.

Four basic tasks were designed: Summarizing a Reading, Self-Testing Vocabulary, Writing Questions and Answers and Diagramming. Seven volunteer Grade 9 Science teachers, with 311 students, were assigned to an experimental and a comparison group. Both groups were asked to follow an outline based on the newly revised Provincial Curriculum for Grade 9 Science. One group was assigned predetermined tasks from the text while the experimental group utilized the tasks above.

In the analysis, the Posttest (with a Problem Solving portion) provided the variables for the Dependent Set while the Pretest, Scores in Grade 8 Science and the Arlin Test of Formal Reasoning provided the variables for the Independent Set. An initial Canonical Analysis determined the relationship between the two sets of variables. An Analysis of Covariance was performed using regression. A Post-Hoc Scheffé Test analyzed contrasts between groups regarding developmental level.

The results showed a statistically significant difference, $\alpha=0.05$, for the comparison group on recall. While the experimental group showed a statistically significant difference on Problem Solving. No interactions were found between the variables and the grouping. Further analysis indicated that while the results were statistically significant, mean score differences were very small. This allowed the observation that while results might be statistically significant they may not be educationally significant. Logs kept by teachers and the researcher provided insight into these results.

Arguments were presented which suggested that the material in the unit taught was incorrectly assumed to be new material by teachers, curriculum developers and this researcher. It was further suggested that this information had become "common knowledge". This prior knowledge interferred with the results and prevented clear answers to the questions asked.

Table of Contents

ABSTRACT ii

LIST OF TABLES vii

LIST OF FIGURES viii

1. INTRODUCTION 1

- 1.1 THE STATEMENT OF THE PROBLEM 1
- 1.2 IMPORTANCE OF THE STUDY 3
  - 1.2.1 Educational Context 3
  - 1.2.2 Experiential Context 5
  - 1.2.3 Theoretical Context 6
- 1.3 THE HYPOTHESES 9
  - 1.3.1 Research Hypothesis 9
  - 1.3.2 Research Hypothesis 10
  - 1.3.3 Research Hypothesis 11
  - 1.3.4 Research Hypothesis 12
- 1.4 METHODOLOGY 14
  - 1.4.1 The Population 14
  - 1.4.2 The Sample 14
  - 1.4.3 Instrumentation 15
  - 1.4.4 The Treatment 16
  - 1.4.5 Research Design 18
  - 1.4.6 Method of Analysis 19
- 1.5 THE LIMITATIONS OF THE STUDY 20
  - 1.5.1 Internal Validity 20
  - 1.5.2 External Validity 20

2. CONTEXT OF THE STUDY 21

- 2.1 RESEARCH ON TEACHING 21

2.2 THE INFORMATION-PROCESSING MODEL 27

2.3 PROBLEM SOLVING 30

2.4 INTELLECTUAL DEVELOPMENT 33

2.5 METACOGNITION AND METAMEMORY 37

2.6 RELATED RESEARCH 40

2.7 SUMMARY 46

3. METHOD OF THE STUDY 47

3.1 THE POPULATION 47

3.2 INSTRUMENTATION 49

3.2.1 Variables To Be Measured 49

3.2.2 Description of the Instruments 50

3.3 EXPERIMENTAL DESIGN 60

3.4 METHOD OF ANALYSIS 63

3.5 VALIDITY 64

3.5.1 Internal Validity 64

3.5.2 External Validity 65

4. RESULTS OF THE STUDY 66

4.1 DESCRIPTIVE STATISTICS 68

4.2 COMPLEXITY OF THE RELATIONSHIP BETWEEN THE VARIABLES 70

4.3 TESTS OF SPECIFIC HYPOTHESES 79

4.4 A DESCRIPTIVE ANALYSIS OF THE RELATIONSHIP BASED ON OBSERVATIONS AND INTERVIEWS 91

4.4.1 Background 91

4.4.2 Discussion Relevent to Specific Hypotheses 96

4.5 DISCUSSION 105

4.6 SUMMARY 111

5. CONCLUSIONS AND RECOMMENDATIONS 113

5.1 PURPOSE OF THE STUDY 113

5.2 CONCLUSIONS 113

5.2.1 Implications of the study on recall 113

5.2.2 Implications of the problem-solving study 121

5.2.3 Implications of the interaction study 124

5.3 RECOMMENDATIONS 126

5.4 UTILITY OF THE STUDY 128

BIBLIOGRAPHY 131

APPENDIX A 137

APPENDIX B 180

LIST OF TABLES

4.1 Data Description 67

4.2 Correlations Between Variables 69

4.3 Canonical Analysis: Test for Multicollinearity of Variables 69

4.4 Bartlett's Test for Significance of Eigenvalues 72

4.5 Canonical Analysis: Summary Statistics 74

4.6 Analysis of Covariance Results for Recall 81

4.7 Means for Recall 83

4.8 Recall Means by Developmental Level - Unadjusted and Adjusted Scheffe Test of Contrasts Between Adjusted Means 84

4.9 Analysis of Covariance Results for Problem Solving 86

LIST OF FIGURES

2.1 Bloom's Model of School Learning 22
3.1 Pretest and Unit Test Questions by Chapter, Topic and Number 53
4.1 Scatterplot Showing Linearity of Relationship Between the First Canonical Variates 71

Chapter 1

INTRODUCTION

1.1 THE STATEMENT OF THE PROBLEM

The general problem of the present study was to determine whether or not teaching-learning strategies, specifically taught for processing information in different ways, enhance achievement in science at the grade 9 level. The questions which arise from this general problem deal not only with achievement but also pertain to the association between the teaching-learning strategies and other factors such as problem solving, previous achievement in science and developmental level. The teaching-learning strategies consisted of a series of assigned student tasks emphasizing encoding, labelling, and self-testing techniques. The strategies were taught to the students in the form of science exercises or assignments using summarizing, diagramming, and two self-questioning techniques. (See Appendix A.) The strategies form four separate types of exercises which were taught as an experimental unit, described as teaching-learning strategies.

It was postulated that when presented with new information these teaching-learning strategies would aid in the internalization and retention of new material in science. This would be accomplished by providing the student with "a set of decision processes that determine what sequences of actions to perform" (Chi,1978,p.74) in order to retain information and result in efficient processing, i.e. labelling and encoding, of information for appropriate retrieval at a later time.

The Subproblems

The first subproblem. The first subproblem was to determine if the implementation of these teaching-learning strategies enhanced the recall of subject matter in a unit of instruction on Energy by grade 9 science students. Coding and labelling are important in building schema or structured networks of informational statements and logical rules for their use. This network is the framework on which interrelated elements in a topic area develop into one conceptual unit (Norman et al., 1976; Cohen,1977).

In a literature review on academic work Doyle (1983) noted:

> Cognitive psychologists argue that a person's knowledge of the world is organized into associational networks or schemata ... A schema is a relatively abstract representation of objects, episodes, actions, or situations which contains slots or variables into which specific instances can be fit in a particular context.
>
> This organizational view of knowledge emphasizes the multiple associations of information in long-term memory. p.166-167

The second subproblem. The second subproblem was to determine if the teaching of these strategies, as noted above, enhanced students' problem solving ability. Brown and DeLoache (1978) found that when novice and expert problem solvers (chess players) were compared the more expert players drew from a more inter-related network of information. Based on information-processing principles, it was surmised that these strategies would enable students to solve problems with greater facility since it would allow them to draw information from a broader range of interrelated elements found within the framework of a conceptual unit.

The third subproblem. The third subproblem was to determine if there was any significant relationship between recall of information and factors such as their previous academic performance in science and level of intellectual development, for those trained in the use of the strategies. Because of the memory enhancement nature of these strategies, it was anticipated that there would be an interaction or relationship between these factors and recall. (Enhancement of problem solving abilities as described in the second subproblem would be an anticipated extention of this interaction.)

1.2 IMPORTANCE OF THE STUDY

1.2.1 EDUCATIONAL CONTEXT

In 1978 the Public Interpretation Panel of the British Columbia Science Assessment judged performance on 70% of the items at the grade 12 level to be less than satisfactory, compared to performance on only 30% of the items judged unsatisfactory at the grade 8 level (p.125). Similar results have been obtained in the 1982 assessment where it was found that:

> The overall picture from the Grade 12 Assessment is very discouraging. No areas of pupil achievement were explored in which it could be said that the pupils were achieving better than "satisfactory", and those areas of satisfaction identified in the Grade 8 Assessments in both 1978 and 1982 do not seem to have been maintained throughout the secondary school years. (British Columbia Science Assessment,1982,p.242)

Thus, an apparent decline in achievement of science appears to occur after grade 8. A hoped for improvement in academic performance and an increased interest and enthusiasm in science at more advanced levels between 1978 and 1982 did not occur. In the 1982 B.C.Science Assessment summary of attitudes toward a career in science it was found that:

> Despite their positive attitude toward science in school and their expressed liking of scientists, pupils in Grades 8, 10, and 12 definitely do not have a high interest in pursuing a career in science. In fact, mean scores were the lowest obtained on the attitude scales... The low results are unfortunate in view of the probable increased need for scientifically talented personel in our future work force. p.245

The 1983 British Columbia Junior Secondary Science Program has as two of its four curriculum goals to "... increase the students' scientific knowledge" and "to provide opportunities for students to develop creative, critical and formal (i.e. abstract) thinking abilities" (p.6).

Since educational research deals with problems of practice within the context in which they exist this study dealt with the problem of designing and justifying teaching-learning strategies in several contexts. Research in a professional field calls for both experience (trained intuition) and ideas from a theoretical framework. The sections which follow draw on both sources.

1.2.2 EXPERIENTIAL CONTEXT

From an experiential perspective, the writer, with eleven years of experience in teaching science at both the junior and senior level, the teaching-learning problem for the student is twofold: first, the facts and information presented to the student must be internalized into a coherent framework; and secondly, the information must be mentally accessible in appropriate problem solving situations. As in most other subjects, it is the writer's opinion, that teachers assume that the learner has developed the capabilities to internalize information naturally in some way as he matures. However, it is suggested that these capabilities are lacking in the grade 9 student and that too often a student is uncertain about what approach to take initially in learning the material. This problem is evident especially in the junior secondary school where science is presented in an entirely different format from other subjects;i.e., within the framework of lecture, demonstration, and laboratory methodologies. It has been found, through experience, that by providing a student with specific directions on HOW to study the factual information presented there is an increase not only in academic performance but also in understanding and, along with understanding, enhanced skill in problem solving.

1.2.3 THEORETICAL CONTEXT

The research within the fields of cognitive development and memory development has indicated that one of the major factors associated with the learning of new knowledge and in the utilization of previous knowledge may be the learning strategies available and used by the learner. Learning strategies appear to play a significant role in determining what information gets learned, how that information is related to previous knowledge, and whether or not it can be retrieved in appropriate situations (Brown and DeLoache,1978).

The importance of this factor is exemplified in Bloom's Model of School Learning where cognitive skills and subject content are the "prerequisite learning held to be necessary for the learning task(s) on which instruction is provided" (Bloom, 1976, p.11).

Further, Doyle (1983) states that

> Research on performance differences has indicated that novices, young children, and low ability students often fail to develop the strategies and higher order executive routines

> that enable them to understand tasks or construct goal structures necessary to accomplish tasks without strong guidance. (p.175)

Gagné (1980) and Janzen (1981) have indicated the need for strategies to be taught along with other types of knowledge and information.

> It would seem that any one or all of these cognitive strategies can be readily learned and that a learner can acquire any one simply by "being told". ...I see no reason to think that there is an advantage for learners to "discover" these strategies, rather than being taught them directly. There appears to be no evidence of such advantage. p.90-91 (Gagné,1980)

Resnick and Ford (1981) in a discussion of discovery learning state:

> Where the aim of teaching is retention and transfer, it may be as effective - and is usually more efficient - to demonstrate the principle directly rather than requiring students to discover it. (p.146)

The teaching-learning strategies in this study were chosen to emphasize the objectives of the lesson through the use of techniques, singly or in combinations, which provide the student with a chance to manipulate elements of a concept. The teaching-learning strategies which seemed to have the most promise, from an experiential view and from those suggested by Biggs (1980) are as follows:

1. Selection of tasks which will require answers that highlight the structural framework or schema of a concept.

   e.g. Teaching specific summarizing, diagramming and questioning techniques which emphasize key words or phrases and identification of superordinate and subordinate ideas.

2. Methods of self-testing to indicate areas of knowledge missing or misunderstood.
   e.g. Use of self-testing vocabulary sheets.

1.3 THE HYPOTHESES

The research and statistical hypotheses which were tested in this study are as follows:

1.3.1 RESEARCH HYPOTHESIS

It was hypothesized, that the use of integrated teaching-learning strategies discussed earlier would enhance the recall of information as determined by the overall academic achievement of students on a Unit Test on recall of factual information. (See Appendix B)

The basis for this conjecture was that the teaching routine provides the connecting link between the subject matter presented in class and the test performance by the students. In a series of studies reported by Resnick (1976) children learned a routine and then "invented a more efficient performance for themselves" (p.72-73). Routines could be thought of as a sequence chosen by a person that puts information into memory. The sequence may or may not be appropriate for the type of information to be stored. With new or novel information different sequences are tried until the person finds one that works. Teaching-learning strategies could be considered as starting points from which more efficient individual routines would develop; therefore, the initial performance by the student should improve since the primary link is given and explained to him rather than the student relying on himself to find a routine for internalizing this new information.

Statistical Hypothesis There would be no statistically significant difference in the amount of variance at the $\alpha=0.05$ level in overall recall of factual material in a unit of instruction on Energy as measured by a recall test of achievment between those using the teaching-learning strategies(the experimental group) and the comparison group.

1.3.2 RESEARCH HYPOTHESIS

It was hypothesized that students using these strategies would not only gain significantly in the recall of scientific information but, in addition, in their ability to solve problems.

Complex material must be learned in more than rote memory fashion if it is to be useful to the individual. In discussing a schematic structure based on the work done in semantics and its relationship to the theory of learning Norman, Gentner, and Stevens (1976) suggest

> the important principle is that the material is organized around schemata. There does not seem to be a homogeneous network structure. Rather there seem to be well structured means for organizing the information, and for functional procedural definitions. Moreover, the schemata provide means for applying the structures to new and to unusual situations." (p.195)

The way in which the teaching-learning strategies were expected to aid in problem solving was through the development of an interrelated conceptual framework built up of factual material.

Measurement of problem solving, in an essay format, was done using a coding system developed by Biggs and Collis (1982), the SOLO Taxonomy (Detailed in Chapter 3). By matching elements of the answer and elements of the concept,certain patterns emerge showing how complete the conceptual framework is by the introduction of irrelevant or invalid ideas.

> Statistical Hypothesis There would be no statistically significant difference in the amount of variance at the $\alpha=0.05$ level between the experimental and comparison groups in the quality of problem solving as measured by the SOLO Taxonomy.

1.3.3 RESEARCH HYPOTHESIS

It was hypothesized that there would be a relationship between students employing these teaching-learning strategies and their developmental level.

As students mature they become more aware of their own repertoire of information processing skills. There is also an increase in the monitoring systems necessary to determine the effectiveness of the strategy they choose for a particular situation (Brown and DeLoache, 1978).

Statistical Hypothesis There would be no statistically significant difference in the amount of variance at the $\alpha=0.05$ level in recall of factual information due to an interaction with developmental level for the experimental group and the comparison group.

1.3.4 RESEARCH HYPOTHESIS

It was generally hypothesized that there would be a relationship between students employing these teaching-learning strategies and previous academic achievement in science. This achievement was measured by the last science grade for a semester course, poor (grade less than C), average (grade C) or good (grade higher than C).

Students who perform well on teacher-made tests may have already learned how to internalize and manipulate scientific information. These students may or may not make use of the specific strategies made available to them in this research. Often academically good students develop more efficient routines (Resnick,1976) (Groen and Resnick, 1977) while with academically poor students the strategies may provide them with a starting point. Resnick (1976) points out that

> differences in learning ability- often expressed as intelligence or aptitude- may in fact be differences in the amount of support individuals require in making the simplifying and organizing inventions that produce skilled performance. Some individuals will seek and find order in the

> most disordered presentations; most will do well if the presentations (i.e., the teaching routine) are good representations of underlying structures; still others may need explicit help in finding efficient strategies for performance. (p.78)

Statistical Hypothesis There would be no statistically significant difference in the amount of variance at the $\alpha=0.05$ level in scores on the Unit Test on recall due to previous academic achievement for the experimental group and the comparison group.

1.4 METHODOLOGY

1.4.1 THE POPULATION

The target population in this study consisted of grade 9 science students enrolled in the public school system within the Province of British Columbia. In this province students have completed a grade 8 science course consisting of units in Chemistry, Biology, Earth Science, and Light. The accessible population consisted of all the grade 9 science classes in a suburb of Vancouver, B.C. These students represented a wide range and diversity of cultural backgrounds and socio-economic levels, as verified by a comparative examination of surrounding communities from the 1981 Census of Canada.

1.4.2 THE SAMPLE

The selection criterion for the sample called for volunteer grade 9 science teachers within a school district. Classes were assigned in such a way as to divide them into 6 experimental and 8 comparison groups. Teachers in the same school were assigned to the same group to eliminate any possible contamination between groups. A total of 7 teachers in 6 schools was used. Also, one comparison teacher withdrew from the study after assignments had been made (this is discussed in Chapter 4). Although the assignment was by intact classes the unit of analysis was the individual student.

1.4.3 INSTRUMENTATION

The instruments used consisted of:

1. Unit Test. This test was compiled for the Energy Unit in the grade 9 text by the author for use as both the pretest and posttest. It consisted of 44 multiple choice recall questions, and 3 problem solving questions requiring essay answers which were added to the posttest. Post-Hoc deletions were made which produced a test with 33 items. Content validity was determined by the teachers involved in the study. Further detail is supplied in Chapter 3. (See Appendix B.)
2. Teaching-Learning Exercises. The teaching-learning strategies were implemented through the use of teachers instructions and classroom/homework assignments. Four teaching exercises were used: Summarizing a Reading, Vocabulary Sheet, Writing Questions and Answers, and Diagramming. (See Appendix A.)
3. Arlin Test of Formal Reasoning. This test was used to determine the developmental level of students involved in this research. Norms are available for grades 6-12 based on 5,000 students. Reliability and validity are provided in Chapter 3, along with a

more detailed description of the test. It also has the advantage of being group administered by the classroom teacher and takes approximately one hour of time to do by most students.

4. SOLO Taxonomy: Structure of Observed Learning Outcomes. This taxonomy was chosen as a means of providing a standardized scoring method for an essay answer. It is a way of quantifying a qualitative attribute;i.e. "how well" the questions were answered. The measure was developed by Biggs and Collis (1982). Each level in the taxonomy identifies an increasing grasp of the material. It identifies responses which proceed from simple to complex manipulation of information relating to a specific topic area and "... provides a measure of the quality of assimilation in terms of progressive structural complexity"(Biggs and Collis, 1982,p.164). (See Appendix A.)

1.4.4 THE TREATMENT

The experimental group received the treatment which consisted of four teaching exercises, the teaching-learning strategies, in the form of tasks which dealt directly with the topics being presented in the class. The task format and function of the format was explained by the teacher using standardized directions. Over time the tasks became familiar to the students and only reminders were given by the teacher.

The comparison group received tasks similar to those the teachers indicate they now give according to the Teacher Survey (part of the B.C. Science Assessment, 1982) where, "... the greatest use [was] of lab/experiment write-ups and completing work unfinished in class with some lesser emphasis on assigning problems at the end of a section or chapter."(p.234) Lab/experiment write-ups were the same for both groups.

Both groups followed a course outline which they assisted in producing for the Energy Unit. This controlled for any sequencing influences and ensured that the content was as close as possible to what would normally be covered. The study took approximately 24 class periods. During that time daily log sheets were kept by both groups of teachers as well as a log kept by the researcher.These provided a reference check against the course outline and kept account of any extraneous influencing variables. The study began at the start of a new school year to control for the Hawthorne Effect. Since four experimental and three comparison teachers were involved and the initial unit of analysis is the student, any teacher effect was controlled for by the number of teachers involved.

1.4.5 RESEARCH DESIGN

The research design used in this study was the nonequivalent control-group design (Cook and Campbell, 1979). It consisted of an experimental group to which six of the fourteen classes in the sample were assigned and a comparison group to which the remaining eight classes in the sample were assigned. The comparison group was a no treatment group who were asked to follow a specific outline and assigned predetermined work from the text. Both groups were given the Unit Test (both as a pretest and a posttest) and the Arlin Test of Formal Reasoning. Both the experimental and comparison groups followed a detailed course outline. Teachers assigned appropriate predetermined tasks to the students. However, the experimental group assignments included directed use of the teaching-learning strategies while the comparison group allowed students to complete the tasks in a manner of the students' own choosing. Results of this study were determined through analysis of the data on the Unit Test, which was used to measure the dependent variable of the study, recall and problem solving.

1.4.6 METHOD OF ANALYSIS

An initial Canonical Analysis was carried out to determine the relationship between the two sets of variables in the study, dependent variables and criterion variables. This provided an overview in which to interprete the following analysis.

Through the use of a Multiple Regression Model an Analysis of Covariance was carried out using scores on the Pretest and Previous Achievement in grade 8 science as the two covariates. The dependent variables consisted of scores resulting from the Unit Test on Recall and on Problem Solving. A Scheffé Test was performed on a Post-Hoc basis to further analyze the students' performance by Developmental Level.

1.5 THE LIMITATIONS OF THE STUDY

1.5.1 INTERNAL VALIDITY

Cook and Campbell (1979) identify four basic threats to the internal validity of this study which are not controlled for by the nonequivalent control-group design itself They are:

1. Selection-Maturation.
2. Instrumentation.
3. Differential Statistical Regression.
4. Interaction of Selection and Local History.

1.5.2 EXTERNAL VALIDITY

The threat to the external validity of the study was due to the non-random selection of the subjects. The analyais found in Chapter 4 substantiates the comparability of the students within the sample. However, extrapolation from the sample group to the general population of grade 9 science students in British Columbia would have to be done with discretion.

Chapter 2

CONTEXT OF THE STUDY

The teaching-learning strategies used in this study have drawn on several large areas of research. They are the result of synthesizing experience and the literature from: research on teaching, information-processing, problem solving, and human development, as well as metacognition and metamemory.

2.1 RESEARCH ON TEACHING

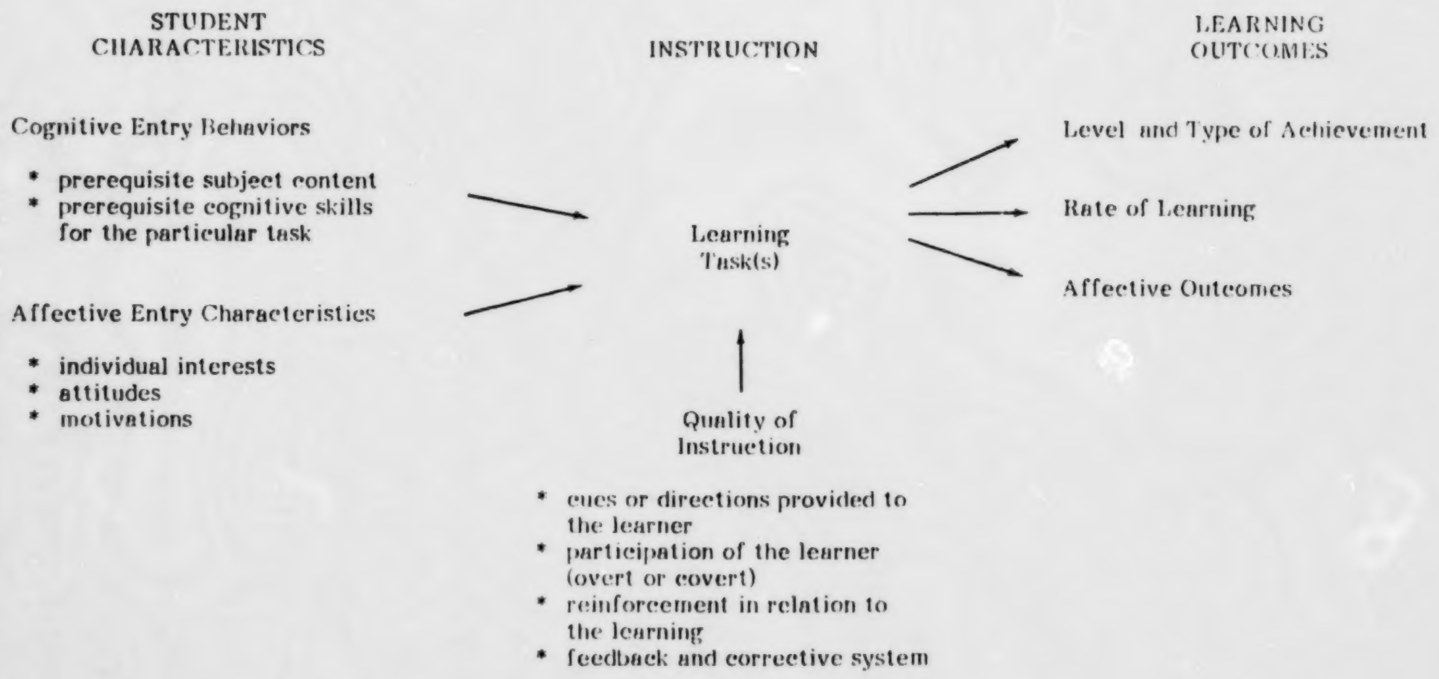
In order to provide a basis from which to view the questions asked Bloom's Model of School Learning was chosen.

Bloom's Model of School Learning (1976) is an expansion and refinement of the work from Process-Product research; i.e., classroom behavior and change in pupil attainment (Dunkin and Biddle, 1974). This model provides a useful framework for a discussion of the interaction involved between teaching and learning.

The model is divided into three segments: Student Characteristics, Instruction and Learning Outcomes. (Figure 2.1)

Under Student Characteristics: Cognitive Entry Behaviors, prerequisite cognitive skills and subject

FIGURE 2.1: Bloom's Model of School Learning (Bloom, 1976)


STUDENT CHARACTERISTICS
INSTRUCTION
LEARNING OUTCOMES
Cognitive Entry Behaviors
* prerequisite subject content
* prerequisite cognitive skills for the particular task
Affective Entry Characteristics
* individual interests
* attitudes
* motivations
Learning Task(s)
Quality of Instruction
* cues or directions provided to the learner
* participation of the learner (overt or covert)
* reinforcement in relation to the learning
* feedback and corrective system
Level and Type of Achievement
Rate of Learning
Affective Outcomes

content, are the "prerequisite learning held to be necessary for the learning task(s) on which instruction is provided" (Bloom,1976,p.11). The Affective Entry Characteristics consist of motivation and interest.

Under Instruction: The Learning Unit is actually a learning task of varying length and specific content coverage. It "may include relatively complex cognitive educational objectives such as analysis or application as well as less complex objectives such as knowledge or comprehension " (Bloom,1976,p.22). Bloom's concern was with the relations between learning tasks and in what ways subsequent learning tasks affect one another in relation to learning outcomes.

He identified the quality of instruction as being the most important variable, assessing it as accounting for 25%-40% of the achievement variance. Bloom uses "level of student participation as a crude index of the presence of good cues and reinforcement for the individual" (Bloom,1976,p.126). From this speculation has come a variety of studies concerning Academic Learning Time. The Beginning Teacher Evaluation Study (Fisher, et al., 1980) found that when teachers gave information about the context of the lesson, explained what the students were to do, provided students with high success activities, and held students accountable, there was greater student engaged time in the activity and greater academic success. This and other activities, resulting from a variety of studies, can be grouped as Direct Instruction. Many of the components are classroom management strategies where "the model [Direct Instruction] improves the quality of instruction by providing appropriate structure for the learning task" (Good,1979,p.58).

Defined by Bloom (1976) "cues include instruction as to what is to be learned as well as the directions as to what the learner is to do in the learning process" (p.115). They can be verbal or visual and may vary in strength.

He notes further that,"In general, we find that students who have developed effective learning and study procedures will be less affected by variations in the quality of instruction than students who have developed less effective learning procedures"(Bloom,1976,p.134).

In work done with teachers' cues and then effects on student achievement Staybrook, Corno, and Winne (1978) found that students did not always perceive cues, such as: indicating important points (structuring), prompting and praise of correct answers (reacting), as learning aids. The only cue to show significant results, in the student's perception of what was happening consisted of questioning, (soliciting) techniques. This is fairly consistent with the experiment on structuring, soliciting, reacting and so on in the Program on Teacher Effectiveness reported by Brophy (1979) where he states that "... no single instructional variable is likely to control enough of the variance in student learning to produce significant results when varied systematically"(p.741).

According to Winne and Marx (1982) process-outcome research postulates that "teachers influence students by causing them to think and behave in particular ways during teaching. These mediating events, in turn, may lead to changes in outcome variables"(p.493). They studied teacher instructional intents and matched them with student perceptions, using stimulated recall. The study concluded that there was a mismatch between teacher intents and student perceptions. Also, with external materials students were more concerned with the task than the orienting component the teacher wanted. However,

> When students were not overly taxed by the amount of the material or the cognitive processing that the teacher intended of them, they were more likely to perceive the instructional stimulus as the teacher intended and to believe they could carry out the cognitive processes they perceived. ... students' ability to perceive and carry out the cognitive processing that teachers cued with instructional stimuli sometimes depended on how well they had mastered content that was to be processed. (p.514)

Therefore, the amount of material is a possible component in a students' ability to perceive a teachers' cue.

In another segment of Bloom's Model, Doyle (1983) looked at Learning Task(s) in terms of Academic Work. He identified four basic types of learning tasks embedded in the content of a class: memory tasks; procedural or routine tasks (i.e., apply appropriate algorithms); comprehension or understanding tasks; and, opinion tasks. A Learning Task may consist of one or a combination of these. The result of the task for a student is that he acquires information or facts and that he practices operations used to produce the information demanded by the task. Further, Doyle (1979) emphasizes the importance of students identifying significant instructional cues.

> ... the information-processing activities of a student are not simply a function of the range of available stimuli or even of the students' personal preferences, rather, they are shaped by the structure of tasks in a given classroom. ...From an ecological perspective, what students learn in a classroom is a function of the operations that they perform in accomplishing tasks.(p.198)

Thus, the setting within the classroom may influence the quantity of material learned.

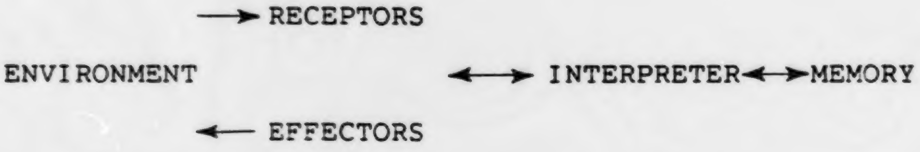
Peterson and Swing (1982) reported on a study which emphasized the problems of focusing on behavior rather than thought processes. They point out that learning is an active mental process. It is the operation chosen by the student which determines the amount of information learned. An

> ... implication of the findings of this study is that teachers should deliberately teach cognitive strategies associated with improved academic performance [such as rehearsing, checking]. This suggestion follows from the finding that students who reported greater use of specific strategies also tended to do better on academic tasks. (p.490)

From this sample of the recent Process-Product literature and with reference to Bloom's Model, it becomes necessary to look at the cognitive processing aspect of academic tasks, processes for conducting a memory search.

2.2 THE INFORMATION-PROCESSING MODEL

The information-processing system abstractly represents the process of knowledge selection, acquisition, and utilization. This is displayed in the following model which shows an interface between the individual and the environment of a receptor of stimuli and an effector of responses to that stimuli.



These two aspects of the system are the visible, basic sources of all incoming and outgoing activity of the individual. It is on these two systems that the theoretical modeling of the internal processing has occured.

At the base of the receptor and effector systems lies the interpreter, also known generally as short-term memory (abbreviated as STM). This provides the elementary information processing or sorting system. Here "decisions" are made on incoming information as to whether it has importance or an association with the basic knowledge base of the individual. Unimportant items are selectively forgotten or ignored, like the ticking of a clock in the background, while other items can be processed for storage with previous information or as seperate units of new information. Newell and Simon (1972) list the functions of the processor as: discrimination of incoming items, tests and comparisons, symbol creation, writing symbol structure, reading and writing externally, designating symbol structures, and storing symbol structures. In summary, the STM system chooses items of import, sorts and classifies, reduces the information into concentrated units for storage, then labels it for retrieval. This process is called encoding and labelling.

The final step in the process is the storage of the encoded information into long term memory (abbreviated as LTM). This area can be considered as a component which stores and retains symbol structures or encoded information until they are retreived by STM for immediate use.

The most characteristic feature of STM is its capacity. Due to the continuous influx of sensory information which must be handled the maximum number of pieces manipulated is 7, plus or minus 2, separate units or chunks of information (Loftus and Loftus, 1976; Chi, 1978). Recoding of the information allows more material to be stored temporarily within this memory section.

Since this capacity is finite, individual decisions are continually made as to the fate of units of information. Some pieces are forgotten , such as a one time phone number, or if the information is important to the individual then the unit is transfered to LTM, such as our own phone number. Because of the coding system, the label referring to "our own phone number" produces retrieval of that particular unit of information from LTM.

The amount of information continually being stored and retrieved presents the individual with certain problems. Temporary inaccessibility can occur when there is an interference such as those caused by previous learning or external events closely associated with the informational unit (Loftus and Loftus, 1976).

The utility of the information-processing model lies in the basic descriptive simplicity of a very complex biological process. The use of the model allows us the ability to separate learning and thought processes into artifical units for discussion and closer investigation.

> Information-processing analyses are clearly distinuished from behaviorist ones... by their explicit attempts to describe internal processing. They differ from the cognitivist Gestalt and Piagetian positions in their attempts to describe the actual flow of performance - to translate 'restructuring' or 'logical operations' into temporally organized sequences of actions. (Resnick,1976,p.64)

It is because of this efficacy that the information -processing model forms the basis of the present study.

2.3 PROBLEM SOLVING

In order for information to be more useful, complex material must be learned in more than a rote memory fashion. Procedures must be learned well enough to be functional when needed as well as when the format varies from the context within which the procedure was learned. (Norman, Gentner, and Stevens, 1976). Therefore, problem solving is conceptualized as the process of the cognitive organization necessary to characterize the type of problem (Greeno, 1978). Problems range from those requiring only the information contained in the problem statement to those requiring a draw on the large stores of information in LTM (Simon, 1978).

Brown and DeLoache (1978) have suggested a pattern for the development of problem solving abilities derived from studies done with novice and expert chess players: first, there is the novice problem solver with little or no intelligent self-regulation;e.g. the confusion over movement of pieces. Second, as familiarity with the rules and subprocesses become familiar an increase occurs in the deliberate self-regulation;e.g., the chess player who starts to anticipate moves. Third, the expert problem solver results only when the subprocesses and their coordination are overlearned to the point where the reaction is at the point of automation.

Gagné (1980) has identified three human capbilities involved in problem solving in apparently essential ways.

1. Intellectual Skill: This enables an individual to perform mental operations which are directly referenced to his environment. The LTM capabilities allow the possibility of carrying out procedures with symbols. These include identifying concepts and applying rules. Solutions to the problem must come after the concepts and rules are learned, although they are usually limited to tasks similar to those found in the rule learning.

2. Verbal Knowledge: Two forms of knowledge are identified: the simplest are the names of objects (declarative knowledge) while the more complex form is composed of organized bodies of knowledge. The increasing store of meaningful knowledge is of critical importance to intellectual development. Within the information-processing model, general knowledge is stressed as an important factor in successful problem solving.

3. Cognitive Strategies: This is the way in which the individual interacts with the environment. These are capabilities which "... may control such processes as attention, perceiving, encoding, and retreival of learned material, as well as ways of thinking" (p.88). These strategies are relevant and specific to certain tasks; therefore, experience is necessary in order to acquire the appropriate strategy for a situation.

As a child matures his mental abilities expand to allow greater use of processes for conducting a memory search. "Better informed about retrieval processes in general, the older child can become more flexible in generating strategies appropriate to the solution of a given problem" (Brown and DeLoache, 1978, p.25.).

2.4 INTELLECTUAL DEVELOPMENT

Within the general framework of the developmental literature, Chi (1978) states that roughly 99% of developmental data indicates that memory improves with age . She states that three factors influence memory development: strategies, knowledge, and capacity. "... a strategy is a set of decision processes that determines what sequences of actions to perform";e.g., rehearsal, recoding, and grouping (p.74). This is similar to the three capabilities, stated before, which Gagné (1980) identified as essential to problem solving;i.e., intellectual skill [from LTM], verbal knowledge, and cognitive strategies.

The work done in task analysis, while reflecting a variety of theoretical positions from Stimulus-Response to Gestalt, all require a successive build up of complex levels on a firm knowledge base (Resnick,1976). Since the necessity of an initial knowledge base is recognized, two factors remain: strategies and capacity [memory]. These will be discussed together since it is felt that they are interrelated.

While looking at learning from a developmental perspective the view taken here is similar to that suggested by Biggs and Kirby (1980) where using the stage concept as a level allows the structure to be "determined by broad endogeneous limits (e.g. in working memory) and by exogeous factors, including instruction, culture. This allows for actively changing the course of development rather than being constrained by the cognitive stages" (p.202).

In general, working memory in an adult is around 7 units as mentioned before. With children the number is smaller, approximately 5 units, although studies with unfamiliar stimuli suggest adults and children perform similarly in memory tasks (Chi,1978). Case (1978) feels that the capacity of working memory does not change after about age 2, but that the measured increase is due to the decrease of capacity required to execute various operations (however, there seems to be little support for the exact age of stability). As developmental stages increase complexity there is a corresponding increased demand for STM capacity (Biggs,1980). Chi (1978) suggests that adults have a developmental difference which allows the encoding of information such as temporal, spatial, and numerical ordering (p.74). Siegler (1978) found that

> ... two children with similar knowledge may be differentially able to acquire new knowledge. Inhelder and Piaget deemphasized this distiction, strongly implying that the same stage considerations that governed existing knowledge determined ability to learn. Subsequent research, however, suggests that the two domains are pragmatically as well as logically distinct. In contrast to the finding that even 16 and 17 year-olds often do not know how to solve formal problems spontaneously, much younger children have been found able to learn to solve them. (p.116)

Case (1977) supports the Neo-Piagetian model of stage transition in cognitive development as follows:

> ... stage transition in any given domain consists of a restructuring of the executive strategy which the child habitually applies to that domain, in order to

> take account of some newly perceived feature of relevance. (p.1)

Within a developmental stage a student experiments with strategies until he gets it right. What he uses as a strategy is dependent on the maximum load in working memory. Therefore, Case (1978) hypothesizes that this is an organismic factor in development.

> ... if the child is actively taught cue discovery and strategy reorganization, then the demends on his working memory should be reduced considerably, either by automization of certain operations or by chunking items that would normally be attended to separately. (p.44)

> ...it seems reasonable to propose that (1) the sequence of behaviors that emerges during the concrete operations period may be ascribed to the evolution of qualitatively distinct executive strategies; (2) progress through any given sequence of executive strategies can be influenced be practice, feedback, cue highlighting, and strategy modeling; and (3) the size of a childs working memory linmits the complexity of the strategy he can acquire and utilize, particularly when his only experience is practice or practice with feedback. (p.44)

To summarize, the difference between students within a level rests upon the ability to effectively group or chunk information for storage in LTM. The strategies necessary to encode this information appear to occur naturally but on an individual time frame. Biggs and Kirby (1980) state that individual differences are thought to be in the quality of processing rather than in the capacity of processing.

This developmental framework is similar to that of Vygotsky where "cognitive development results from learning experiences in which children are taught to use various cognitive skills through social interactions with others"(Camperell,1981,p.5). Cognitive processes are seen as social phenomena which must occur twice: first at a social external level between individuals [similar to Case's feedback above] and second on a personal internal level which Vygotsky terms "inner speech". "The concept of inner speech function mirrors the American construct of metacognition. In both constructs, inner-speech and metacognition, self-regulatory skills are defined as routines people use to plan, monitor, and direct their own cognitive behavior based on insights they have about how their own minds work"(Camperell,1981,p.5).

2.5 METACOGNITION AND METAMEMORY

Two broad areas dealing with theories of learning are found in recent literature. Since both areas deal with concepts of learning in the sense of a higher, more developed level the term meta is used as a prefix. The two areas are Metacognition and Metamemory.

"Metacognition involves the monitoring and regulation of information-processing strategies. As a subset of metacognition, metamemory is concerned with the monitoring and regulation of memory processes and strategies used by the individual..." (Lawson,1980,p.145).

Because metacognition is concerned with the deployment of the learning strategies which determine the process used, the teaching-learning strategies encountered in this research could be defined within the metacognitive literature. However, the function of the teaching-learning strategies is to enhance learning which requires a functional memory system. Cavanaugh and Perlmutter (1982) discuss the logic of metamemory as follows: Piaget's concepts of assimilation and accomodation "imply an active memorizer". Even though Piaget "did not argue explicitly that knowledge about memory [metamemory by definition] is crucial for memory development... he focused on development of the logical structure of memory content"(p.13). The executive processes referred to in metamemory literature refer to the mechanisms which orchestrate cognition;i.e., selecting the best strategy, monitoring efficiency and effectiveness of ongoing memory processing, updating strategies, responding to tasks, and so on. One difference between the immature and the mature memorizer is the use of spontaneous memory strategies. Cavanaugh and Perlmutter (1982) state that it is the processes which should be distinguished from metamemory. They identify this as the point of confusion over the definition which in turn has resulted in research problems.

Baker and Brown (1980) add further to the semantic difficulties identifying Metacognitions reference to two separate phenomena:

1. knowledge about cognition: "... a person's knowledge about his own cognitive resources and the compatability between himself as a learner and the learning situation"(p.2).
2. regulation of cognition: "... consists of the self-regulatory mechanisms used by an active learner during an ongoing attempt to solve problems. These indices of metacognition include checking the outcome of any attempt to solve the problem, planning one's next move, monitoring the effectiveness of any attempted action, testing, revising, and evaluating one's strategies for learning"(p.3).

Thus, even though much of the recent research in the following section can be classified as Metamemory there is an overlap into Metacognition, and vice versa. In perusing the research it is suggested that the strategies being discussed can be adequately interpreted through the use of the information-processing model, thereby eliminating the semantic problems encountered when using the more recent terminology of Metamemory and Metacognition.

2.6 RELATED RESEARCH

Much of the research in strategy training is related to the study of reading and is frequently aimed at the mentally retarded or educable mentally retarded. It is only within the last few years that this research has expanded into the regular classroom with the work on Concept Mapping and Vee Mapping.

Brown, Campione, and Day (1980) identify three general types of training found in the literature on rote recall, which is the most commonly studied strategy involving rehearsal, categorization, and elaboration.

1. Blind Training. Students are induced to use the strategies but are given no explicit details of the activity. "... they fail, however to result in maintenance or generalization of the strategy - i.e., the child neither uses the activity subsequently of his own volition, nor transfers the activity to similar learning situation"(p.5).
2. Informed Training. Students are induced to use the strategies and are given some information on the significance of the activity. "These training packages result in both improved performance on the training task and maintenance of the activity by the child when faced with subsequent similar problems. There is some evidence of generalization, but so far the evidence has been very weak, and the transfer very near-i.e., the

generalization task is very similar to the training task"(p.7).

3. Self-Control Training. "... the child is not only instructed in the use of a strategy but is also explicitly instructed in how to employ, monitor, check and evaluate that strategy. The number of studies that have employed this combination are few, but preliminary results do indicate that the strategy-plus-control training packages are the most successful at inducing not only enhanced performance but also transfer of training to appropriate settings"(p7.).

In a study of summarizing readings done by Brown, Campione, and Day (1980) in which self-control training was taught they found that by including the self-monitoring strategy they were able to induce the rudiments of mature studying behavior. These self-monitoring strategies can consist of self-questioning techniques, summarizing and studying from a summary, underlining, estimating readiness to be tested, and so on (Baker and Brown,1980). Brown and Barclay (1976) in a study done with educable mentally retarded students suggest an interrelationship between cognitive maturity and suseptability to training, with older students apparently spontaneously monitoring a strategies effective use. Since the present study utilized a sample of children a normal range of ability, it would seem that teaching self-monitoring techniques would require only an initial introduction for the students to perceive a value in them.

In a study on the use of retreival aids to enhance recall Baker and Brown(1980) concluded:

> Thus, the ability to select suitable retrieval cues is a late-developing skill because it requires a fine degree of sensitivity to the demands of studying. The successful user of the flexible retrieval plan ... must have (a) information concerning the current state of knowledge, i.e., what her knows of the text and what he does not yet know; (b)knowledge of the fine gradation of importance of various elements of texts,i.e., what is important to know and what can be disregarded; and (c) the strategic knowledge to select for retrieval cues information that he missed previously. (p.38)

If this ability is a "late-developing skill" then a natural extention of the statement is: how late in developing? In a study on teaching a hierarchically organized program (Eylon,1979) using 36 first year university physics students, the two with the lowest ability remembered very little and with no coherent organization. They admitted no framework even though the material was highly structured. Eylon suggested that "lower-ability subjects lacked some organizational processing skills (such as exploiting a hierarchical organization presented to them, or reorganizing information by themselves)"(p.103). Further, she suggests that a desirable goal may be to teach these organizational skills (p.104). Therefore, even at the university level with at least average ability students the same lack of strategies for effective processing can be found.

Other formats were found in teaching the use of strategies, however these consist of a more formalized and structured scheme.

The first, is the RSM2P of Huhn (1981). This requires the teacher to personally model and aid in the students learning of the strategy. The teacher must first engage in retrospection of the specific task, then perform the task, next he must note what is done and thought along with any influences which affect decisions. Then the sequence must be taught to the student.

1. Rationale: explain what the student is being taught and why.
2. Steps: the teacher provides the steps in writing and goes over them orally.
3. Model: the teacher models the use of the steps orally.
4. Practice: the students goes over the steps orally with the aid of the teacher.
5. Practice:the student is given a number of similar tasks to perform independently.

It is suggested that this technique would be labelled convergent thinking by Dirkes(1980). Where learners learn by rules without their own input; therefore,what they are really learning is how to substitute (p.1).

Baker and Brown (1980) discuss another study technique developed by Robinson in the 1940's called SQ3R. The acronym denotes: Survey, Question, Recititation, Reflection, and Review. However, this technique assumes that the student has various strategies for encoding information, summarizing, and recall.

More recently Novak and Godwin (1984) have developed and researched two new teaching-learning strategies called Concept Mapping and Knowledge Vee Mapping. These are both based on Ausubel's Assimilation Theory of Learning. Briefly, the theory states that a learner builds on what he already knows. By a process of subsumption new knowledge is added to the knowledge base. But for new knowledge to be utilized it must be meaningful to the learner rather than knowledge learned by rote memory.

Novak's Concept Mapping finds its basis in the epistemologies of Kuhn and Toulmin where "concepts, not methods of inquiry, are at the core of rational human thought, including the rational basis of science and mathematics". Concepts are "... regularities in facts designated by some culturally agreed upon sign or symbol..." usually joined together by propositions, such as "clouds give rain" (Novak,1977,p.455). With Concept Mapping a student draws a hierarchical structure connecting concept words together. This technique can be taught even to very young school children. The teacher must correct the concept maps individually since variations do occur as th student builds upon his previous knowledge (Novak and Gowin, 1984).

Gowin's Vee Mapping requires that all parts of a problem be considered concomitantly and interactively. A student builds the Vee Map by identifying all parts of the conceptual and methodological background knowledge which affects the present question being asked . In this way the final answer to the question or problem has a very definite place within the hierarchical knowledge structure the student has built up (Gowin, 1981).

Novak, Gowin, and Johansen (1983) report the use of Concept Mapping and Vee Mapping with high school science students. With grades 7 and 8, concepts had to be explained first and then, with practice, the student progressed from concept mapping to the use of Vee maps for their lab work. After six months there were statistically significant differences in problem solving abilities between those using the techniques and a control group, although there was "relatively low mean performance of both experimental and control classes" (p.638). While recall also improved significantly the highest correlations occurred between these techniques and course grades. The authors estimated that with two or more years of working with Vee Maps 90% of the students would become highly competent with its use (p.635).

However, in a study with Black High School students comparing outlining techniques with Concept and Vee Mapping Lehman, Carter and Kahle (1985) found no statistical difference between groups. (This study is mentioned further in Chapter 5 with regard to the results of the present research.)

2.7 SUMMARY

When students encounter a large amount of information, particularly if it is unfamiliar knowledge such as that found often in science, they must have ready techniques to process it. Using the Information-Processing Model the limited STM capacity necessitates useful, economical strategies to store that informaion into LTM and to allow for successful retrieval. These useful, economical (in terms of STM space) strategies result from concise methods, with personally proven utility, which are practiced by the student to the point of automation. As an individual matures these strategies usually develop naturally over time. However, as found in a variety of studies, these strategies can also be taught. The time involved to teach these strategies appears to depend on the type and age of the student as well as the complexity of the technique.

Chapter 3

METHOD OF THE STUDY

3.1 THE POPULATION

The target population of this study was grade 9 science students in the province of British Columbia. The accessible population consisted of grade 9 science students in a school district within the greater Vancouver area. This community compared proportionally to the Greater Vancouver Regional District with respect to income, religion, origin of the population and types of dwellings (1981, Census of Canada). These students had completed one year of grade 8 science which included units in Chemistry, Biology, Earth Science, and Light. Intact heterogeneous classes were used; i.e., students were not separated according to their abilities. The students from this district represented a broad range of cultural backgrounds and socio-economic levels.

The Sample

The selection criterion were that the teachers in the sample instruct heterogenous grade 9 science classes, with respect to ability, and volunteer to participate in this study. Using these criteria, a sample of 7 teachers with a total of 14 class consisting of 388 students participated in the study. The teachers and classes were organized as follows: two teachers had one class each, three teachers had two classes each and two teachers had three classes each.

Students who were repeating grade 9 science (24 students) and those for whom data were incomplete (53 students) were deleted at the end of the study resulting in a sample population of 311 students. Since the incomplete data consisted of information from students tested several times on various occasions as well as from permanent record cards, data was considered to be missing on a random basis.

3.2 INSTRUMENTATION

3.2.1 VARIABLES TO BE MEASURED

The Dependent and Independent variables of this study are identified as follows:

DEPENDENT VARIABLES

1. Recall of facts as measured by the Unit Test.
2. Problem solving as measured by the Unit Test.

INDEPENDENT VARIABLES

1. Treatment: A teaching-learning strategy based on the principles of information processing, Group 1. Comparison: A regular teaching-learning strategy, not directly based on the principles of information processing, Group 2.
2. Developmental level, as measured by the Arlin Test of Formal Reasoning.
3. Previous academic achievement, as measured by score obtained in grade 8 science.
4. Prior knowledge of the material to be taught as measured by the Unit Test, a Pretest.

3.2.2 DESCRIPTION OF THE INSTRUMENTS

1. Unit Test: The Unit Test was used as a measure on the dependent variables and as a measure of prior knowledge of the Unit, an independent variable. This test was compiled by the researcher based on information found in the Energy Unit in the grade 9 text. It consisted of two types of questions: I. Recall;e.g. multiple choice, and II. Problem Solving; e.g. essay questions where content information must be manipulated. The content was judged by the teachers as validly reflecting the course taught.

During the spring prior to the research several teachers volunteered to give tests on the Energy Unit to the grade 9 students they were teaching at the time. Some of these teachers later participated in the present study. The two versions of the test consisted of a total of 69 multiple choice questions. The UBC LERTAP Programme was used to conduct a statistical item analysis. From this bank of 69 questions 44 were accepted for use in the Fall and made up the Unit Test.

The Pretest consisted of the 44 multiple choice questions identified as being statistically acceptable during the previous school year. It was administered within four days of the beginning of the school year. The Hoyt estimate of reliability=0.43, with a standard error of measurement of 2.94. The Posttest was the same test given to students at the end of the Energy Unit, six to ten weeks after taking the Pretest. At this point an item analysis was performed again using the UBC LERTAP Programme. A post-hoc analysis identified 11 items to be statistically unacceptable and were deleted. The same items were subsequently removed from the Pretest as well, on a post-hoc basis. This resulted in a Unit Test of 33 items (Table 3.1). The Pretest Hoyt estimate of reliability=0.35, standard error of measurement=2.57. The Posttest Hoyt estimate of reliability=0.75, standard error of measurement=2.61.

The Essay portion of the Posttest consisted of three problem solving questions requiring essay answers (from Pieper and Beauchamp, 1936). Teachers were asked to code the answers for complexity using the SOLO Taxonomy (described later in this chapter). Half-way through the study the teachers were asked to code some essay questions which gave them practice with using the Taxonomy, these were not used in the analysis. A linear regression was performed comparing the coding from a random sample of each teacher's coding with another person's coding of the same answer. Using Snedecor and

Cochran (1980), Table A II(i), the significance levels of the correlation

TABLE 3.1: Pretest and Unit Test Questions by Chapter, Topic & Number

Chapter	Topics	Pretest Questions (Posttest Questions)
1	Energy - definition	31(7)
	Energy forms	13(4)
	Potential and Kinetic	9(37) 15(8) 34(28)
	Energy transformations	17(44) 37(34)
2	Force - definition	8(21) 41(15)
	Measuring force	19(28)
	Gravity - Mass	14(5) 12(23)
	Friction	24(40) 28(36) 43(30)
3	Work - definition	11(18)
	Calculating work	10(2) 20(12)
4	Simple machines	1(9) 21(8)
	Pulleys	30(41)
	Levers	38(17)
	Common simple machines	4(11)
5	Acceleration - deceleration	2(14) 39(31)
	Balanced forces	25(38) 33(16)
	Inertia	5(27)
	Newton's First Law	29(24)
6	Law of Energy Conservation	18(10) 44(22)
	Converters - efficiency	27(42) 40(20)
	Power	23(33) 26(43)
7	Energy transformation	22(29) 42(25) 35(1)
	Energy of particles	8(32)
8	Conduction	8(19) 36(38)
	Convection	18(35)
	Infra-red radiation	7(13)
	Insulation	32(3)

Underlined numbers indicate items which were deleted on a Post-Hoc basis.

coefficient were within the a=0.02 for all but one teacher who did not fulfill this requirement. All of the essays from this teacher were recoded by the researcher. Another inter-rater reliability was carried out with the results being within the 2% significance level.

2. Treatment:Teaching-Learning Strategies: The strategies were formulated into four specific types of assignments for the teacher to follow. They were:
I. Summary of a reading (after the work of Brown, Campione, and Day, 1980)
II. Vocabulary List with a Self-Testing feature.
III. Written Questions and Answers (after the work of Andre and Anderson, 1978).
IV. Diagramming and Simplifying Concepts. This was an extension of the other three assignments.

All assignments were outlined on an exercise sheet with respect to directions, purpose, and the physical layout of expected results. An introduction was given by the teacher, along with a brief exercise to demonstrate how the work was to be done. On the first exercise the directions and an example was provided for the students. They were used alone and in combinations depending upon the specific type of content objectives. The general exercise format for each assignment or combination of assignments as they relate to the Information Processing Model is as follows:

a. Encoding

   1) Assignment I. Write a short summary of approximately 1-3 sentences for each paragraph assigned to be read using the summarizing directions.

   2) Assignment II. Draw a simple diagram showing the structure of the item, for example, a lever. Label each part.

   3) Assignment III. Write a question based on a section which has been read and then answer it.

b. Labelling

   1) Assignment I. and IV. Choose one or two words in each of the above sentences which could be considered to be the identifying word for the ideas expressed.

   2) Assignment I. and IV. With a diagram choose the key or important parts which need to be remembered.

c. Encoding and Labelling

Assignment II. Using a three columned sheet - write the key words in the first column and a definition or description in the third column. The definition or description must be short enough to fit in the space provided.

d. Retrieval or Self-Testing

1) Assignment II. Later fold the third column to the back and write the definitions in the middle column. Leave blank any terms not known. Using another sheet set up the same format, write out the words and definitions or descriptions missed.

2) Assignment IV. Try to answer again the questions developed from the sections read in the chapter being studied.

3. Developmental Level: Arlin Test of Formal Reasoning: This test was used to determine developmental level. It consists of 32 objective items giving an overall total test score on 8 subtests of conservation of volume, probability, correlations, combinations, proportions, forms of conservation beyond direct verifications, coordination of two or more systems of reference and mechanical equilibrium. The overall readability is at the grade 6 level. Norm referenced data exists for grades 6-12. Arlin (1982) points out that:

> the multitrait-multimethod matrix indicates the possiblity of developing an objective measure of Inhelder and Piaget's formal operational schemata that can validly and reliably parallel an individual's performance in the clinical setting... The Test of Formal Reasoning furnishes a gross assessment of levels, and its subtests afford diagnostic tools and measures for curriculum development projects. Its value is in the provision of reliable and valid information about cognitive levels of groups

> of individuals so that information about the cognitive levels and characteristics of large groups of students can be utilized for instruction and curricular decisions. p.107

This test was administered to each group of students within the time of a single class period. Since this test was given within the first five days of the new school year the total test statistics are based on 398 students. The results reflect categorical levels;i.e., Piagetian stages in developmental level, thus the test statistics should be viewed with this in mind. The mean=14.17 with a standard deviation of 4.48 on the 32 item test. Range=4-31 questions and the Hoyt estimate of reliability=0.69 with a standard error of 2.44.

4. Problem Solving: SOLO Taxonomy: This taxonomy was developed by Biggs and Collis (1982) to provide a scheme for categorizing student responses in terms of their complexity. In describing the Taxonomy, Biggs and Collis (1982) outline it as follows:

> The overall term for the structure of the observed learning outcome is SOLO:and the levels of prestructural, unistructural, multistructural, relational, and extended abstract are isomorphic to, but logically distinct from, the stages of pre-operational, early concrete, middle concrete, concrete generalization and formal operational, respectively,
>
> Four main dimensions are used to categorize responses: working memory capacity, operations relating task content with cue or question and response, consistency within a response and relative necessity for closure in making that response, and general overall structure, which results from the interaction between

the previous dimensions. p.31

Reliability on this test was through an inter-rater reliability check of the teachers from randomly chosen samples as described in the Unit Test above.

5. Course Outline: An outline was developed by the teachers and researcher for both the experimental and the comparison group. The basic material covered was kept as close as possible to their normal classes. The differences occured in the exercises assigned for work in class or as homework. The experimental group was given work based on the four assignments or combinations of them. The comparison group was assigned work based on questions from the textbook. The work assigned to each group had been prepared so as to equate the time and content coverage as closely as possible.
6. Teacher's Daily Log: This log provided an opportunity for the teacher to note any deviations from the course outline, such as changes in a lab due to equipment problems. It also provided a daily record for comparison between the course outlined and the course implemented, although the teachers adhered to the outline very well.
7. Researcher's Log: This log provided for an added check on adherence to the course outline. It also allowed for a record of possible deviations and any extraneous variables which may have affected the

results of the study.

8. Exercise Tally Sheets: These sheets were for recording the completeness of the exercises or assigned tasks. It used a decimal system for ease in averaging. These sheets were not for grading of the assignments, but rather provided a further means for classroom observation.
9. Independent Variable: Previous academic achievement was obtained from school records. Usually these are recorded as letter grades without averages.

Each teacher was given a booklet with information pertinent to the group to which he had been assigned. Examples of the completed booklets are given in Appendix A. All tests which were administered can be found in Appendix B.

3.3 EXPERIMENTAL DESIGN

The design for this research was that of a nonequivalent control-group (Cook and Campbell, 1979). Two groups were formed: an experimental and a comparison group.

A pretest was given to both groups. The pretest and the posttest, called a Unit Test, were based on the Energy Unit. Since a span of six to ten weeks was involved the issue of practice was not considered to be a factor. Within the time span of teaching the unit two smaller tests were given to both groups. These tests were not used in the analysis but rather, allowed the teacher an opportunity to obtain a grade for each student for that segment of the course. Since one of the smaller tests included two essay questions it provided an opportunity for a preliminary inter-rater reliability check on the categorization of the problem solving questions for use on the Unit Test.

Teachers were asked to assist in developing and to adhere to a course outline based on the British Columbia Grade 9 Energy Unit in Developing Science Concepts in the Laboratory (Murphy and Schmid, 1979).

Individual training was held for both groups in June, at which time each teacher was given a booklet containing all information necessary for completing his portion of the study. This allowed all teachers a chance to look over the material at their leisure during the summer. They were contacted again in August before school started and the researcher reviewed the study again on an individual basis.

The explanation for the experimental group covered the following:

1. the rationale for the strategies.
2. the directions for the exercises along with examples.
3. the rationale and directions for the course outline which included specific strategies matched to a particular lesson.
4. the rationale and directions for the daily log.
5. the function of the researchers' log.
6. a discussion of the categorization levels for the essay questions which will occur on the Unit Test.

The explanation for the comparison group covered the following:

1. the rationale and directions for the course outline which included specific homework questions from the textbook matched to particular lessons.
2. the rationale and directions for the daily log.
3. the function of the researchers' log.
4. the function of the comparison group in this research (the particular questions to be investigated were not discussed).

The students in the experimental group received the teaching-learning strategies for a concept or objective as a single sheet or set of sheets. The exercise sheets were explained by the teacher using suggested directions. The teachers introduced the strategies and explained to the students the rationale, intended outcomes of the exercises, and the correct use of the strategies and exercises. Often this involved doing examples on the board with the class. These explanations provided the student with the objective of the exercise in terms of the concept and the organization of the sheets. At the beginning of the next class or at the next opportune time the teacher went over the assignment with the class. All exercise sheets were kept in the students' notebooks. Students corrected their own work but the teacher kept a record of completeness of the task and offered individual directions where needed.

The comparison group was assigned questions found at the end of a reading or chapter to control for any effects due to practice or rehearsal. The teacher went over the tasks with the class. Again, students corrected their own work but the teacher kept a record of completeness of the task and offered individual direction where needed.

3.4 METHOD OF ANALYSIS

The Unit Test was divided into two parts. After the Post-Hoc adjustments described earlier, Part I contained 33 multiple choice questions, while Part II contained 3 essay or problem solving questions (Appendix B). Summary results on the final Unit Test was arranged according to total number of recall questions correct and the specific categorical levels given in the essay or problem solving questions. A post-hoc analysis of the Unit Test, using the UBC LERTAP Program, ensured the check of Part I. An inter-rater reliability was done on a random selection of the categorization in Part II for each teacher, as detailed earlier.

Procedure For Analysis

An initial Canonical Analysis was performed to provide an overall view of the relationship between the two sets of variables in question. A multiple regression model was used with reductions occuring in the model where statistically appropriate.

An Analysis of Covariance was performed using Pretest and Previous Achievement in grade 8 science as the two covariates. A Scheffé Test on the Post-Hoc analysis of Developmental Level was performed on the contrasts between groups on recall.

3.5 VALIDITY

3.5.1 INTERNAL VALIDITY

Cook and Campbell (1979) suggest that this design controls for all but four threats to internal validity. The control for these threats were as follows:

1. Selection-Maturation. Since intact classes were used starting at the beginning of a school year it was assumed that all students would mature equally in both groups.
2. Instrumentation. Initial inspection of the pretest frequency distribution determined the comparability of the groups. The pretest and postest were the same test in order to control for differences in testing instruments.
3. Differential Statistical Regression. Since the students were chosen from heterogeneous classes there was no deliberate selection of extreme subgroups.
4. Interaction of Selection and History (Local History). This involves events other than the treatment which may affect the experimental and/or comparison groups. Teachers were made aware of this problem and asked to note this in the log. A

researchers' log as well as a teachers' was kept to ensure precise recording of events extraneous to the study.

3.5.2 EXTERNAL VALIDITY

The community chosen for this study was a suburb of the city of Vancouver. The population adequately represented a wide spectrum of socio-economic and cultural diversity. However, due to the non-random selection of subjects the extrapolation of results to the target population of all Grade 9 science students in British Columbia would have to be made with discretion.

Chapter 4

RESULTS OF THE STUDY

The purpose of this study was to determine whether or not teaching-learning strategies, specifically taught for processing information in different ways, enhance the achievement in science at the grade 9 level. The dependent variables used were recall of information and problem solving; while, the independent variables consisted of any previous knowledge about the specific subject matter to be taught, students' developmental level, previous achievement in grade 8 science, and group membership; i.e., membership in the experimental group or comparison group.

The results are presented in five parts and provide different but complementary perspectives of the study.

1. Descriptive Statistics.
2. Complexity of the Relationship Between the Variables.
3. Tests of Specific Hypotheses.
4. Qualitative Analysis Based on Observation and Interviews.
5. Discussion.
6. Summary.

TABLE 4.1: Data Description

	Post-Test		Essay		Pre-Test		Arlin Test Reasoning		Prev. Ach.	
	Exp.	Comp.	Exp.	Comp.	Exp.	Comp.	Exp.	Comp.	Exp.	Comp.
Maximum	30	33	4.30	3.17	20	21	5	5	6	6
Minimum	4	7	0	0	4	4	1	1	1	1
Range	26	26	4.30	3.17	16	17	4	4	5	5
Interquartile Range	3.5	4.0	0.58	0.42	1.5	2.5	0.5	0.5	1.5	1.0
Variance	28.08	28.12	1.16	0.70	8.20	10.56	0.91	0.88	1.81	1.92
Standard Deviation	5.30	5.30	1.08	0.84	2.86	3.25	0.95	0.94	1.34	1.34
Mean	17.35	18.84	1.73	1.26	10.51	10.83	2.70	2.67	3.60	3.48
Standard Error	0.44	0.41	0.09	0.06	0.24	0.25	0.08	0.07	0.11	0.11
Median	17.00	19.00	1.67	1.33	10.0	11.0	2.0	2.0	4.0	3.0
Standard Error	0.58	0.58	0.05	0.10	0.29	0.58	0.29	0.29	0.29	0.29
Mode	17.00	17.00	0	0	10.00	12.00	2	2	2	2
Skewness	-0.03	-0.07	0.02	-0.05	0.41	0.33	0.53	0.37	0.19	0.24
Kurtosis	-0.44	-0.44	-0.49	-0.79	0.17	0.11	-0.72	-0.72	-1.02	-0.91

FREQUENCY TABLE

Arlin Test of Formal Reasoning						Previous Achievement						Sex				
		Experimental		Comp.				Experimental		Comp.			Experimental		Comp.	
Code		N	%	N	%	Code		N	%	N	%		N	%	N	%
1	COCN	6	4.1	10	6.0	1	Pass	3	2.1	7	4.2	Male	62	42.8	86	51.8
2	HICN	72	49.7	75	45.2	2	C-	35	24.1	43	25.9	Female	83	57.2	80	48.2
3	TRAN	31	21.4	43	25.9	3	C	34	23.4	36	21.7					
4	LOFM	32	22.1	35	21.1	4	C+	32	22.1	40	24.1					
5	HIFM	4	2.8	3	1.8	5	B	27	18.6	23	13.9					
						6	A	14	9.7	17	10.2					

4.1 DESCRIPTIVE STATISTICS

Table 4.1 gives a summary of the descriptive statistics for each variable in the analysis by group, experimental or comparison. The tests used to measure the variables of interest in this study are listed for both the experimental and comparison group with their relevant statistics. The Arlin Test of Formal Reasoning has been coded by level as: 1-Concrete, 2-High Concrete, 3-Transitional, 4-Low Formal and 5-High Formal. This coding is continued within Table 4.1 in the Frequency Table along with the appropriate coding for Previous Achievement. The Frequency Table indicates the numerical code, categories, number and percentage for Developmental Level (ATFR), Previous Achievement in Grade 8 science and Gender. A break down by Gender is also included for both groups. Two items should be emphasized; first, how similar the two groups are with respect to the range and variety of factors measured, and second, the skewness and kurtosis are negative, indicating extended lower tail and a slightly flattened normality distribution.

Table 4.2 indicates the low to moderate linear relationship between the variables measured. Of particular note are the correlations between variables of 0.30. According to Snedecor and Cochrane (1980,p.182) the estimated proportions of variance shared for an $r=0.30$ is only 0.09 or 9%, thereby making anything lower than that correlation a weak relationship.

TABLE 4.2: **Correlations Between Variables**

		1	2	3	4	5
Recall	1	1.00				
Problem Solving	2	0.22	1.00			
Pretest	3	0.35	0.21	1.00		
Development Level	4	0.45	0.14	0.35	1.00	
Previous Achievement	5	0.48	0.22	0.19	0.26	1.00

TABLE 4.3: **Canonical Analysis: Test for Multicollinearity of Variables**

Squared Multiple Correlations of Each Variable in Set One with Variables in Set One

Variable	R-Squared
Recall	0.05
Problem Solving	0.05

Squared Multiple Correlations of Each Variable in Set Two with Variables in Set Two

Variable	R-Squared
Prior Knowledge	0.14
Developmental Level	0.16
Grade 8 Scores	0.08
Group Membership	0.01

4.2 COMPLEXITY OF THE RELATIONSHIP BETWEEN THE VARIABLES

Since human knowledge and learning is such a complex phenomenon it is rationally not feasible to perceive of each factor as an independent variable, unique and without influence on another variable despite the low to moderate correlations between variables seen in Table 4.2.

Levine (1977) points out that

> Using conventional multiple regression techniques, the usual approach would be to regress each dependent variable or index of each subconcept on the set of independent variables one at a time and in some arbitrary fashion combine the several results. There would be no opportunity to investigate the possiblity that combinations of dependent variables relate to combinations of independent variables. It is specifically that capability of analyzing the relationships between sets of variables-many-to-many patterns of association as opposed to one-to-many patterns resulting from multiple regression - that makes canonical correlation a useful technique . . . p.11

It is with this rationale in mind that Canonical Analysis was carried out as an initial study of the relationship between variables.

The analysis was performed in order to determine the number and nature of the dimensions along which the dependent variables, recall(Posttest) and problem solving (Essay), were related to the independent variables; prior knowledge (Pretest), developmental level (Arlin Test of Formal Reasoning [ATFR]) and previous achievement in grade 8 science (Prev. Ach.).

FIGURE 4.1: Scatterplot Showing Linearity of Relationship Between the First Canonical Variates

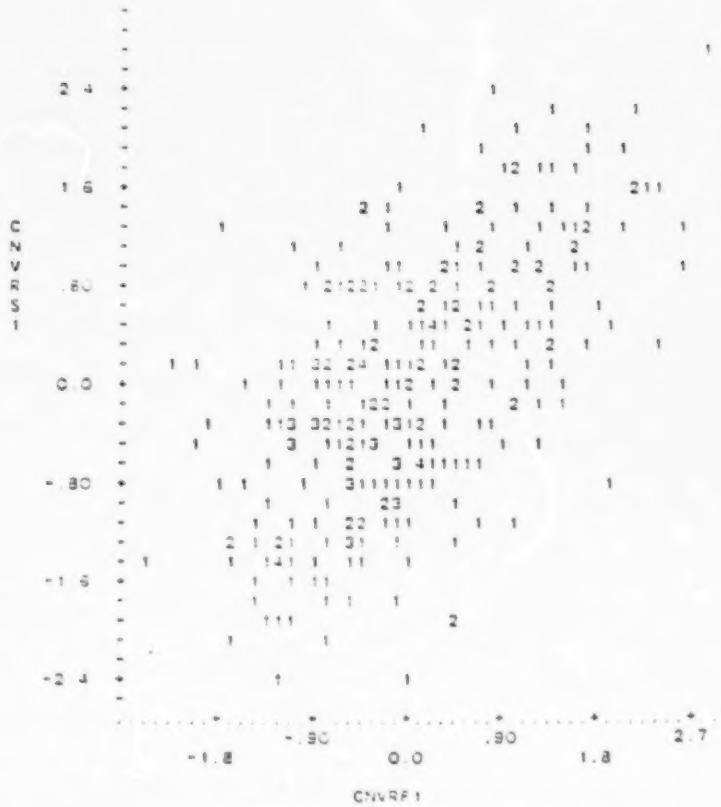


TABLE 4.4: Bartlett's Test for Significance of Eigenvalues

Eigenvalue	Canonical Correlation	Chi-Square	df	p
0.40	$R_{C_1} = 0.63$	183.19	8	0.00
0.09	$R_{C_2} = 0.30$	28.32	3	0.00

Assumptions: An examination of the normality assumption on which a canonical analysis is based indicated that the skewness and kurtosis of the variables were not excessive.

The standardized score values were within ±3.00 standard units indicating no outliers. Table 4.3 shows an absence of multicollinearity. No missing cases were included. The plot presented in Figure 4.1 indicates that the assumption of linearity of relationship between the first canonical variates is tenable. Thus, the assumptions on which the canonical analysis was based were satisfactorily met.

Results: Table 4.4 presents the canonical correlations obtained along with the results of the Chi-square test for statistical significance. The first canonical correlation was 0.63 while the second canonical correlation was 0.30. Only two canonical correlations were possible since the smallest set of variables contained only two variables. The Chi-square tests were statistically significant $\chi^2(8)=183.19$, $p < .0001$, and $\chi^2(3)=28.82$, $p < 0.001$. Therefore, the two canonical correlations were statistically significant.

Table 4.5 provides the Summary Statistics of the canonical correlation analysis. Columns I and II describe the two pairs of canonical variates $\hat{Y}(1),\hat{X}(1)$ and $\hat{Y}(2),\hat{X}(2)$, respectively. Columns IA and IIA show the structure

TABLE 4.5: Canonical Analysis: Summary Statistics

	I First Canonical Variate ($Y^{(1)}$)		II Second Canonical Variate ($\hat{Y}^{(2)}$)	
	A Structure Coefficients	B Standardized Coefficients	A Structure Coefficients	B Standardized Coefficients
Dependent Variable Set				
Recall	0.99	0.98	-0.09	-0.31
Problem Solving	0.30	0.09	0.95	1.02
Percent of Variance	54%		46%	Total = 100%
Redundancy Index	21%		04%	Total = 25%
	($\hat{X}^{(1)}$)		($\hat{X}^{(2)}$)	
Independent Variable Set				
Prior Knowledge	0.56	0.28	0.05	0.08
Developmental Level	0.71	0.46	0.03	-0.05
Grade 8 Scores	0.73	0.62	0.26	0.22
Group Membership	-0.18	-0.20	0.97	0.97
Percent of Variance	37%		25%	Total = 62%
Redundancy Index	15%		02%	Total = 17%
Canonical Correlation, R_c	0.63		0.30	
Eigenvalue, λ_i	0.40		0.09	

coefficients or correlations between the canonical variates and the original variables. The standardized canonical weights in Columns IB and IIB indicate the relative importance of each original variable to the corresponding canonical variate.

Examination of the structure coefficients and standardized canonical weights given in Columns IA and IB reveal that the first dimension underlying the dependent variables is primarily a recall dimension (structure coefficient=0.99), and that the first dimension underlying the independent variables is essentially a cognitive dimension which almost entirely excludes group membership (structure coefficient=-0.18). These results suggest that performance on the recall task by the two groups had very little to do with whether or not the subjects received the teaching-learning strategies. Columns IIA and IIB reveal that the second significant dimension underlying the dependent variables is a problem solving dimension (structure coefficient =0.95), and that the second dimension underlying the independent variables is primarily a group membership dimension (structure coefficient=0.97). The correlation between the problem solving dimension and group membership dimension is marginal (canonical correlation=0.30) which suggests that there only was a weak linear relationship between performance on the problem solving task and membership in the experimental or comparison group. Overall, then, the canonical analysis points to a moderate relationship between the dependent variables and the independent variables, and that this relationship is complex in that there are two dimensions underlying the two sets of variables. Examination of these dimensions reveal that there only is a weak relationship between problem solving and group membership while recall is primarily a function of the cognitive variables and not group membership.

The Percent of Variance reveals the average amount of variance of a canonical variate that can be accounted for by the original variables composing the variate. It provides an indication of how well the new variate, $\hat{Y}(1)$ for example, represents each dependent variable within the set. In this instance, the original Y-variables account for approximately 54% of the variance in the first canonical variate, $\hat{Y}(1)$, and about 46% of the variance in the second canonical variate, $\hat{Y}(2)$. Thus, about half of the variance in these two Y-composites is unaccounted for by the variables, Recall and Problem Solving. Only 37% and 25% of the variance in the canonical variates, $\hat{X}(1)$ and $\hat{X}(2)$, respectively is accounted for by the original independent variables, Prior Knowledge, Developmental Level, Grade 8 Scores and Group Membership. The Percent of Variances results suggest that there is considerable variance in the Y and X composite which is unaccounted for, presumably due to other factors. The Redundancy Index shows the amount of variance in the canonical variate of one set which is accounted for by the variables of the other set. This means that for the first canonical variate, 21% of the variance in the $\hat{Y}(1)$ is accounted for by the variables in the Independent variable set. While for the second canonical variate only 4% is accounted for by the second set of Independent variables, a very low percentage particularly if this study was to be used for prediction purposes.

The analysis of the Standardized Coefficients indicating the relative order of importance of the variable underlying the first dimension, Recall (0.98), for the first set was: Grade 8 scores (0.62), Developmental Level (0.46), Prior Knowledge (0.28) and Group Membership (-0.20). For the second set - Problem Solving (1.02) the variable with the greatest influence was group membership (0.97), with the other cognitive variables providing only a relatively weak connection to Problem Solving; Grade 8 scores (0.22), Prior Knowledge (0.08) and Developmental Level (-0.05). Supported by both the structure coefficients and the pattern analysis of standardized weights cognitive variables appear to provide the underlying support for Recall in the first dimension while in the second dimemsion group membership, treatment, is the primary support variable.

In summary. the canonical analysis suggested that the relationship between the two sets of variables was modest (0.63) and two-dimensional, One dimension underlying the first set of variables having to do with Recall and the relatedness of the cognitive variables while the other dimension was defined primarily by the relationship between achievement on the Essay questions and group membership (experimental or comparison).

4.3 TESTS OF SPECIFIC HYPOTHESES

This section will deal only with the Statistical Analysis. Part 4.4 will provide the qualitative background necessary for the interpretation of the results in Part 4.5. This will allow all available information to be utilized in examining and interpreting the results.

The Full Multiple Regression model used for the analysis was:

$$Y_{ijk} = \beta_0 + \beta_1 X_{ijk1} + \beta_2 X_{ijk2} + \beta_3 X_{ijk3} + \beta_4 X_{ijk4} + \beta_5 X_{ijk5} + \beta_6 X_{ijk1} X_{ijk3} + \beta_7 X_{ijk2} X_{ijk5} + \beta_8 X_{ijk3} X_{ijk4} + \beta_9 X_{ijk3} X_{ijk5} + \varepsilon_{ijk}$$

Y_{ijk} = Recall (post test)
X_1 = Prior Knowledge (pretest)
X_2 = Previous Achievement
X_3 = Factor A - Treatment
X_4, X_5 = Factor B - Developmental Level
X_6 = Pretest - Group Interaction (Covariate interaction)
X_7 = Previous Achievement - Group Interaction
X_8, X_9 = Factor AB Interaction
i = 1, 2, ... 311 Subjects
j = 1, 2 Levels of Factor A
k = 1, 2, 3 Levels of Factor B

Table 4.6 details the result of the Analysis of Covariance which was performed, using prior knowledge of the unit (Pretest) and previous achievement in science (Grade 8 scores) as the two covariates. An analysis of equality of slopes and the interactions between the factors support the hypothesis of homogeneity of slopes and no significant interaction effects between Factors A and B.

Thus, this analysis allowed for a reduction of the model as follows:

$$Y_{ijk} = \beta_0 + \beta_1 X_{ijk1} + \beta_2 X_{ijk2} + \beta_3 X_{ijk3} + \beta_4 X_{ijk4} + \beta_5 X_{ijk5} + \varepsilon_{ijk}$$

Y_{ijk} = Recall (Post test)
X_1 = Prior Knowledge (Pretest)
X_2 = Previous Achievement
X_3 = Factor A - Treatment
X_4, X_5 = Factor B - Developmental Level
i = 1, 2, ... 311 Subjects
j = 1, 2 Levels of Factor A
k = 1, 2, 3 Levels of Factor B

TABLE 4.6: Analysis of Covariance Results for Recall

Source	Prop. of Variance	SS	df	MS	F	p
Full Model						
Interaction - Both Covariates	0.003	7.19	2	3.60	0.75	> 0.05
Interaction - AXB Group X Development Level	0.003	7.19	2	3.60	0.51	> 0.05
Reduced Model						
Pretest + Achievement ($R^2y.12$)	0.30	2656.34	2	1328.17	48.22	< 0.05
Adjusted						
Factor A Group	0.02	177.09	1	177.09	5.08	< 0.05
Factor B Development Level	0.08	708.36	2	354.18	20.30	< 0.05
Residual ($1-R^2y.12345$)	0.60	5312.69	305	17.14		
TOTAL	1.00	8854.48	310			

Shown in Table 4.6, further tests of the null hypothesis resulted in statistically significant main effects at the α=0.05 level, thereby indicating a statistical difference between means on recall with respect to group and developmental level.

In Table 4.7 unadjusted and adjusted means are shown for the Factor A effect, Group. Since Table 4.6 indicates a statistically significant difference on recall and taking into account the effect of systematic variations from the covariates, Table 4.7 identifies the comparison group performing better than the experimental group. Of note in the table is the very slight change made by the experimental group after adjustments as well as no change in the mean for the comparison group. This supports Pedhazur's (1984,p.505) comment that any covariate whose correlation with the dependent variable is less than 0.30 does not increase the precision of the analysis.

In Table 4.8 unadjusted and adjusted means are shown for the Factor B effect, Developmental Level. A Scheffé Test of Contrasts Between Adjusted Means indicates that students with a higher Developmental Level performed significantly better when compared with students at lower levels. Further, as mentioned before there was no group by developmental interaction, thereby upholding the use of the ANCOVA model, thus the difference in performance was due to

TABLE 4.7: **Means for Recall**

	Unadjusted	Adjusted	Standard Error
Experimental:	17.35	17.36	0.44
Comparison	18.84	18.84	0.41

TABLE 4.8:

Recall Means by Developmental Level
Unadjusted and Adjusted

	I Concrete	II Transitional	III Formal
$\bar{Y}$	15.94	19.40	21.52
$\bar{Y}$ ADJ	16.83	19.36	20.66

Scheffé Test of Contrasts
Between Adjusted Means

Comparisons	$\hat{\psi}$	MSc	95% C.I.
$\bar{Y}$.IADJ - $\bar{Y}$.IIADJ	-2.53	0.27	(-3.19, -1.87) *
$\bar{Y}$.IADJ - $\bar{Y}$.IIIADJ	-4.30	0.27	(-4.96, -3.64) *
$\bar{Y}$.IIADJ - $\bar{Y}$.IIIADJ	-1.30	0.34	(-2.14, -0.46) *

* $p < 0.05$

the maturational differences indicated by the various developmental levels.

For Problem Solving, the Full model used was:

$$Y_{ijk} = \beta_0 + \beta_1 X_{ijk1} + \beta_2 X_{ijk2} + \beta_3 X_{ijk3} + \beta_4 X_{ijk4}$$

$$+ \beta_5 X_{ijk5} + \beta_6 X_{ijk1} X_{ijk3} + \beta_7 X_{ijk2} X_{ijk5} + \beta_8 X_{ijk3} X_{ijk4}$$

$$+ \beta_9 X_{ijk3} X_{ijk5} + \varepsilon_{ijk}$$

Y_{ijk} = Problem Solving (Essay)
X_1 = Prior Knowledge (Pretest)
X_2 = Previous Achievement
X_3 = Factor A - Treatment
X_4, X_5 = Factor B - Developmental Level
X_6 = Pretest - Group Interaction (Covariate Interaction)
X_7 = Previous Achievement - Group Interaction (Covariate Interaction)
X_8, X_9 = Factor AB Interaction
i = 1, 2, ... 250 Subjects
j = 1, 2 Levels of Factor A
k = 1, 2, 3 Levels of Factor B

TABLE 4.9: **Analysis of Covariance Results for Problem Solving**

Source	Prop. of Variance	SS	df	MS	F	p
Full Model						
Interaction - Both Covariates	0.00	1.88	2	0.94	0.79	> 0.05
Interaction - AXB Group X Development Level	0.00	0.28	2	0.14	0.16	> 0.05
Reduced Model						
Pretest + Achievement ($R^2y.12$)	0.12	16.40	2	8.20	9.65	< 0.05
Adjusted						
Factor A Group	0.10	15.03	1	15.03	33.67	< 0.05
Factor B Development Level	0.03	4.10	2	2.05	3.33	< 0.05
Residual ($1-R^2y.12345$)	0.76	103.88	244	0.43		
TOTAL	1.00	136.68	249			

Table 4.9 shows the Analysis of Covariance results for Problem Solving with prior knowledge of the unit (Pretest) and previous achievement in science (Grade 8 scores) used as covariates. An analysis of equality of slopes and the interactions between the two factors supported the hypothesis of homogeneity of slopes and no significant interaction effects between Factors A and B.

Thus, this analysis allowed for a reduction of the model as follows:

$$Y_{ijk} = \beta_0 + \beta_1 X_{ijk1} + \beta_2 X_{ijk2} + \beta_3 X_{ijk3} + \beta_4 X_{ijk4} + \beta_5 X_{ijk5} + \varepsilon_{ijk}$$

Y_{ijk} = Problem Solving (Essay)
X_1 = Prior Knowledge (Pretest)
X_2 = Previous Achievement
X_3 = Factor A - Treatment
X_4, X_5 = Factor B - Developmental Level
i = 1, 2, ... 250 Subjects
j = 1, 2 Levels of Factor A
k = 1, 2, 3 Levels of Factor B

Table 4.9 indicates that there are significant main effects, Group and Developmental Level, after adjusting for both covariates. The proportion of variance in Problem Solving accounted for by each factor after adjustment for both covariates was 10% and 3% respectively. The Canonical Analysis, Table 4.5, confirmed the results that Problem Solving was more closely related to Group Memebership (Treatment) than to Developmental Level.

Referring back to Table 4.2 it can be seen that the correlations between problem solving and the other variables is less than 0.30 (Pretest=0.21, Developmental Level=0.14, Previous Achievement=0.22) therefore any systematic variations would not significantly increase the precision of the ANCOVA (Pedhazur,1984,p.505). For this reason unadjusted mean scores were compared. The unadusted mean scores on Problem Solving for the two groups was as follows:

Group	Unadjusted Mean	Standard Error
Experimental	1.73	0.09
Comparison	1.26	0.06

Therefore, the difference in means of 0.48 was statistically significant at the α=0.05 level with the experimental group achieving a higher mean score on problem solving than the comparison group.

Summary By Hypotheses

A. The first hypothesis tested was:

There will be no statistically significant difference between the two groups in the amount of variance accounted for at the $\alpha=0.05$ level, in overall recall of factual material in a unit of instruction on Energy as measured by a recall test of achievement.

Table 4.6 summarizing the Analysis of Covariance indicates a statistically significant difference between groups at the $\alpha=0.05$ level on recall of factual information, with the comparison group obtaining a higher mean score.

B. The second hypothesis being tested was:

There would be no statistically significant difference in the amount of variance at the $\alpha=0.05$ level between the experimental group and the comparison group in the quality of problem solving as measured by the SOLO Taxonomy.

Table 4.9 summarizes the Analysis of Covariance which indentified a statistically significant difference between groups on problem solving with the experimental group obtaining a higher mean score.

C. The third hypothesis being tested was:

There would be no statistically significant difference in the amount of variance in recall of factual information due to an interaction between developmental level and group at the $\alpha=0.05$ level.

Table 4.6 shows that the analysis yielded no statistically significant differences at the $\alpha=0.05$ level on recall by group due to developmental level.

D. The fourth hypothesis being tested was:

There would be no statistically significant difference in the amount of variance in scores on the Unit Test for recall due to an interaction between previous academic achievement and group at the $\alpha=0.05$ level.

Table 4.6 shows that there was no statistically significant difference at the $\alpha=0.05$ level on recall by groups due to previous academic achievement in science.

4.4 A DESCRIPTIVE ANALYSIS OF THE RELATIONSHIP BASED ON OBSERVATIONS AND INTERVIEWS

This section consists of two parts: a Background of the study and a Discussion Relevant to the Specific Hypotheses.

4.4.1 BACKGROUND

While this study was taking place the teachers and the researcher kept a daily log of events. These records were intended to be used to assist in the interpretation of the statistical analysis, they were not meant to provide materials for ethnographic study or content analysis. Therefore, actual conversations and confidences are being respected, with pertinent information being utilized only as they reflect on the study.

Since this was a field study the amount of control had to be weighed against the reality of the normal functioning of a classroom. The students were unaware of the study being conducted and teachers were encouraged to proceed in as normal a manner as the constraints of the study allowed. The research began in September at the start of the new school year so that the students would not perceive anything different being done. Several students did ask the teachers why the assignments were different from those in grade 8 but they accepted the explanation that the teacher wanted to do things a little differently this time. In one instance it took a repeating student with the same teacher 2 1/2 months to ask why things were different from the previous year. Therefore, it was felt that the results from the students are valid indications of the amount of material learned.

Class meetings were approximately 50 minutes in length with a range of schedules from daily science classes (a 5X5 schedule) to five class meetings every nine days (a 5X9 schedule). The teachers' logs indicated some substitute teachers due to illness and some class interruptions for administrative business (i.e., class pictures) but all of this is a normal part of the school year. Neither of these factors appears to have interfered with the study and are considered part of the average classroom routine.

Although the groups were statistically similar on the variables measured it was the opinion of two teachers that the students in one part of town were "better" than students elsewhere. They indicated that these students came from homes where the parents were professionals rather than blue collar workers. Students from this area were represented in both groups, although there were more of these students in the comparison group.

While the teachers were asked to use discretion and not openly discuss the study (an attempt to control for contamination between groups) most of the teachers mentioned that they had a good idea of who was taking part. Towards the end of the study several teachers confided this knowledge and assured me that they had not discussed details with anyone. The teachers appeared similar in their desire to have their students perform well.

The seven teachers involved represented a very wide range of experience, talents and expertise in science teaching.

In the experimental group: one teacher had been trying to implement something similar to what was being studied in the research and for that reason asked to be put into the experimental group (his bias was noted). Another teacher did not appear to fully understand the rationale of the study and therefore had some problems with implementing the materials, despite repeated attempts to assist him. The third teacher appeared to be harried at times due to other commitments in the school. With these last two teachers, students with "A" and "B" averages were separated and assigned to other classes and teachers during the summer. This was beyond our control and the disparity was noted. These students were in the geographical area of "better" students. Therefore, with these two teachers, the best students within the "better" group were not proportionately represented in the experimental group. The fourth teacher liked the materials and also included his group of repeating students in the study on an informal basis. These students were not included in the analysis but are discussed later in the chapter.

Within the comparison group: two of the teachers had some problems at times due to other commitments in the school but did follow the outline. The third teacher reacted to the various educational and political events which were occuring in the Province at this time. A fourth teacher in the comparison group withdrew from the study since he felt too much constraint by following the unit outline. He also had not participated in developing the outline during the Spring; although, he had been sent all of the material and been encouraged to respond.

All teachers in the study cooperated fully, offering comments and suggestions as the research progressed. The only universal comment was some slight frustration at keeping to a fairly rigid outline; although they all understood the necessity for it.

The political and educational events occuring in the Province and community became evident through comments referring to concern for job security, teacher layoffs, larger class sizes, and budget restraints. The influence of this could cause a Hawthorne Effect; i.e., by making the teacher feel that the students' performance reflected on him as a teacher he would put extra effort into teaching the unit. However, if there was any increase in effort it was not apparent in any of the statistical analysis. Any influence of these events on the students would be purely speculative.

While there were some differences on test performance between teachers they were not enough to be evident when the students were placed in larger groups. This could imply a very minimal teacher effect. This provides an interesting point and one which should be noted especially when the diversity of teaching styles, teaching skills and backgrounds are taken into account.

The teaching-learning materials were acceptable to the teachers who used them. The two teachers who fully understood the rationale appeared the most satisfied with them. All four teachers were still using the material even though the study had ended. They reported that the material was easy to use and that with a minimum amount of class time spent on training the students had no trouble with it. There were unsolicited comments from the students about the use of the materials in other classes. One teacher noted that at the end of the unit his grade 9 class had more students who were in a passing range than any other class he was presently teaching, or compared with the classes from the previous year. He felt that the materials assisted those borderline students who otherwise would have failed the tests. In particular, one borderline student made tremendous progress, resulting in the highest grade in the class on the Posttest. It should be noted that this increase in achievement by a "poor" student is not supported by the statistical data. This may suggest an influence on individual students which does not show up in differences between group means. However, this particular teacher continued to say that he would use the materials no matter what the study showed and any non-significant results he would consider to be due to sample size. Again it should be noted that the data is based on a reasonable sample size for the questions being asked. Perhaps what these comments suggest is that the experimental teachers are finding some utility to the material which is not apparent in the statistical analysis.

4.4.2 DISCUSSION RELEVENT TO SPECIFIC HYPOTHESES

A. (Reference to Hypothesis 1) The statistically significant result of the comparison group in the recall section of the Unit Test indicates a need to scrutinize the results of the experimental group. It is possible to attribute this difference to a number of factors including, "better" students in the comparison group, interference with learning a new technique by the experimental group, or the experimental materials failing to perform in the manner theorized. An analysis of the groups found that the experimental group was composed of fairly different subgroups while the comparison group had relatively uniform subgroups with which to begin the study. This may have also interferred with the results obtained. To fully deal with any of these speculations further research would be necessary. Therefore, while acknowledging the discrepancy between the hypothesized functioning of the experimental materials and the actual quantitative results, to continue the analysis of the study will be discussed only within the constraints of the available information. Despite the fact that the analysis proved statistically significant, it is important to note that the canonical analysis showed that when group membership was combined with the other cognitive variables it proved to be the weakest influencing factor in recall. For a teacher, any changes that could improve a student's performance by shifting his letter grade when compared to a control group could be seen as educationally significant. While the results were statistically significant, for a teacher, it would become a matter of rationally judging whether or not a difference of 1.5 (unadjusted) points on a 33 question test is educationally significant. The phrase educationally significant is used here to mean a reasonable and realistic difference which a classroom teacher would consider to be enough to warrant a change in his teaching methodology. Kirk (1978) points out:

> Critics of hypothesis testing procedures have observed that the population mean is rarely equal to the exact value specified by the null hypothesis and hence by obtaining a large enough sample virtually any H_0 can be rejected. For this reason it is important to distiguish between statistical significance, which leads to the decision that $\mu \neq \mu_0$, and the practical significance, which means that the difference $\mu - \mu_0$ is large enough to be useful in the real world. p.232

As a teacher, I would suggest that there is not enough of a difference in the two means to warrant any kind of generalization either way on the merits of the experimental material. It is better to make statements based on conservative grounds especially when dealing with the nuances of human learning. Therefore, it is suggested that while the difference between the two groups on Recall is statistically significant, the results could be considered as educationally non-significant.

One teacher who worked with the "better" group of students expressed surprise, and some disappointment, at the results of the Posttest. He thought they should have done better. This would be a natural expectation given the perception that several teachers had of the students in this part of the community. And yet, there basically was not that much difference between his group and any other class involved in the study. A teacher in the experimental group, with students who appeared quite different from the previous group mentioned was pleased with the way his students worked and the way they performed on the test. He too had expectations which differed from the results.

B. (Reference to Hypothesis 2) The coding on the problem solving, Essay, section was performed using the SOLO Taxonomy. A review of the pertinent code is as follows:

Category 1
-avoids the questions, refuses to answer or simply guesses.
-repeats or restates the question.
-makes an irrelevant, personally based association.
Category 1.5
-inadequately uses potentially relevant information but only partially grasps a significant point.
Category 2
-selects 1 relevent aspect from the evidence and correctly answers with that.
Category 2A
-selects 2 relevant aspects that are inconsistent or unrelated and, therefore, draws no firm conclusion from them.
Category 3
-selects 2 or more relevant points from the evidence but ignores any inconsistencies and makes no integration or connection.
-facts are written as isolated points with no

relationship given, no firm conclusion is reached.

Category 3A

-recognizes inconsistencies but is unable to resolve them, or makes only a partial integration of the facts.

Category 4

-uses all or most of the relevant information and integrates it with a relating concept, reconciling any conflict but remaining within the given context.

-the conclusion drawn may be invalid outside of the specific context of the question.

Category 4A

-recognizes the relativity of the explanation, but inadequately makes use of abstract principles that override context. Attempts to use an abstract idea but uses it incorrectly.

Category 5

-uses abstract principles that show the example is just one of many possible results or explanations.

-uses deductive reasoning from the information.

-no firm decisive answer, shows that the outcome may be different with other data or in another context.

The use of this code allows an incorrect answer to be given a numerical grade of <2. Therefore, any grade of <2 indicates a wrong or incomplete answer. The unadjusted average answer in Problem Solving was 1.73 for the Experimental Group and 1.25 for the Comparison

Group. In both groups the average answer was basically less than 1 relevant response drawn from what they had been taught.

It is important to point out that according to the canonical analysis a very small influence on problem solving came from cognitive factors, most of it came from group membership. This means that very little of the information presented in class was transferred to answering the essay questions, even though the students should have been cued by it being a science test. Most responses consisted of 1 or 2 sentences and were often accompanied by drawings. Frequently the answers could be classified as "common knowledge", such as the response to why your back stays cold when facing a fire, which was "The heat goes up the chimney". With an overall unadjusted mean of 1.46 it implies that very little thought went into the answers especially since the answers could have been obtained by the manipulation of straight recall of facts. (The problem solving questions were based on information found in the Energy Unit.)

Some teachers reported problems with students who were writing answers to the essay questions. They said that students did not understand the directions, which requested answering in as much detail as possible, and the title "Essay Questions" on the test had them ask how could they answer without going to the library. It is possible that in attempting to keep the questions direct and concise it caused some students to perform other cognitive manipulations with the information or required further thinking before they attempted to deal with the questions being asked. However, there were no reports from the teachers about any student having problems understanding the questions , only the directions. Also, by definition, a problem and problem solving occurs when no immediate, apparent answer is available. Information must be manipulated. And yet, it becomes questionnable whether or not the essay portion of the test was actually measuring problem solving. Logically, what was probably being measured was the students' writing skills. Therefore, it is suggested that the experimental group performed better due to the writing practice they obtained from using the teaching-learning materials rather than from any increase in problem solving ability.

This example of the apparent lack of thought is often one of the "frustrations" which a grade 9 teacher must contend with from his students. At one point in the study a teacher noted that the materials and idea were good but that the age group was probably inappropriate, an older group was suggested. Since it was pointed out in Chapter 1 that this age is where the problems in science first begin to appear, if this suggestion is followed, it may be more advantageous to teach these strategies to a younger group. Another teacher who was also teaching this technique to his grade 8's noted that they had no problems learning how to use the materials.

C. (In reference to the hypothesis dealing with the influence of group membership and developmental level on recall.) The Arlin Test of Formal Reasoning was explained to the teachers but was only discussed with regard to the rationale for the test and giving it to the class. Only one teacher requested the results, but never commented on them. The analysis showed that there were differences on achievement according to the developmental level of the students. This indicates that those students with higher reasoning abilities perform better than those students at a lower level.

D. (In reference to the hypothesis dealing with group membership and previous achievement in grade 8 on recall.) The scores on grade 8 science elicited a number of comments from the teachers. When the grades were obtained from record cards one teacher expressed surprise at how close they were to the grades given on the current report card. He felt that a teachers' grade was probably the best indication of a students' ability and performance. This was the concensus among all of the teachers. With the exception of some individual students the teachers saw the grade comparisons as being the same. This was supported by the canonical analysis as well as by the overall analysis which was performed to address this specific hypothesis.

4.5 DISCUSSION

The following discussion attempts to combine both the quantitative and qualitative aspects of the study which have been presented.

Approaching the teaching-learning materials from a theoretical perspective it has been shown in Chapter 2 that they are in part based on work done in Reading (Brown, Campione, and Day, 1980; Andre and Anderson, 1978) where they worked quite successfully, and they are similar to the techiques advocated by Novak (1984). Novak and his colleagues have based their theories on Ausubel's Hierarchical approach to learning. Since the resulting intent of Novak's material is similar to the one in this research it is suggested that the theory on which the present materials are based is supported by two different theories of learning; i.e., Ausubel's Hierarchical Model and Information Processing Model. The similarities are also supported in the study by Lehman, Carter and Kahle, 1985. In order to determine the validity of this suggestion further research would be needed on the theoretical grounds of Information Processing, learning and transferral of metacognitive strategies.

Since the teachers acknowledged that their usual assignments centered around the types of work that the comparison group was doing; i.e., answering questions, it may be stated that the comparison group was not doing anything out of the ordinary. The experimental groups needed some training in choosing the key ideas or concepts in a reading. One teacher said that for some students he had to point out that the definition of a word does not always come after the word, sometimes it is embedded in the sentence before the highlighted word. Another teacher was pleased with the rules for summarizing and even worked with one class to summarize a reading on the board because they were having so much difficulty. The hardest assignment for the experimental group was writing questions and answers. Typically, they wrote single word response type questions. Therefore, it appears that the experimental group was actually being assigned something different from the comparison group. This is important since it underscores the fact that the two groups were different in this respect.

Time is a key component in any study of this type, namely, learning to learn (Koran and Koran, 1984). If time was a factor involved it should be noted that the time and material equalled one-quarter of the course which the teacher is expected to cover. It will be recalled that this spanned six to ten weeks. From a realistic standpoint it would be anticipated that if any differences were to be seen they should have shown up, or at least started to become apparent, within 25% of the total instructional time.

An interesting and key feature in reviewing the analysis was found in the raw scores on the Pretest. The average unadjusted score (the total number correct) after a post-hoc item adjustment was 10.68, with a range of 6 to 21.

This was on a 33 question test. Apparently the students already knew an average of 1/3 of the material before they began the class, with some students knowing 2/3 of the material. This is a crucial point in understanding the results of the study. Since the topic of Energy is not part of the grade 8 curriculum and often science as a specific subject area is not taught in the elementary schools (Science Council of Canada Study 52, 1984) it would be a natural assumption on the part of teachers, as well as curriculum developers, that the students did not have a basis in Energy. (Here Energy is being discussed within its scientific meaning and not in relation to a student's preconception of Energy.) The grade 9 science program has been recently reworked, with new texts being issued in 1979. However, in going back to the material used before this renewal it is obvious that many of the topics and experiments were retained from the 1968 version.

Perhaps the movement in the 1970's to promote general public awareness of energy has influenced these students to a point where their general knowledge is greater than students who entered grade 9 in the 1960's. If the students are entering with a background in Energy then it may explain why so many of the answers to the essay questions were "common knowledge" rather than utilizing factual or "new" information available from recall.

From the results of the canonical analysis only 40% of the variance in the Unit Test was accounted for. A natural question to follow this would be what other factors might be influencing the results. Since the Pretest asked very specific questions it is possible that the students have a broader and more varied background in Energy than was anticipated. If students actually do have this knowledge base it could be anticipated that by making the Pretest broader more of the variance could have been measured and accounted for.

Earlier in this chapter it was mentioned that a class of students repeating grade 9 science with one of the experimental teachers was included in the study on an informal basis. These 17 students had a Pretest average of 11.79 correct answers and a Posttest average of 12.76 correct. The Pretest score was approximately the same as other students just beginning the course (10.68 compared to 11.79). While it must be noted that these students are generally poor in other classes as well, it is interesting that the Pretest-Posttest difference is approximately 1 question correctly answered. With the two groups in the study the difference was approximately 8 questions correctly answered. What these two items may point out is: if a student already knows or is familiar with a topic, how much more will he learn by going over it again? If this is a reasonable question to ask then it may be assumed that even with greater maturity and intellectual development students on an average could not glean any more than they already have from the material, especially since curriculum developers choose the topics and presentation specifically for this age group. This small increase of 8 questions correctly answered may only be a reflection of relearning and adding on more information to a knowledge base. If teachers expected this material to be new then it is obvious why a teacher of "better" students would be surprised and disappointed in the results of the Posttest (mentioned earlier).

While the following discussion refers to ATI studies it is included here to emphasize the influence which previous knowledge has on any study concerned with learning techniques.

As far as the experimental material is concerned, in a discussion of the influence of prior knowledge in studies of learning to learn, Koran and Koran (1984) do an excellent job of summarizing Tobias (1976).

> In an attempt to integrate a number of Attribute Treatment Interaction studies using prior knowledge as an aptitude variable (Tobias,1976), it was noted that alternative programmed instructional conditions were less likely to produce significant differences when material was used with which students were familiar. Conversely, with novel content, it was generally found that eliciting student responses, providing feedback concerning them, and tight organization of the instructional material made substantial differences in student achievement. These findings led to the statement of a general hypothesis predicting an inverse relationship between prior knowledge and amount of instructional support required to attain instructional objectives. p.798

This would support the findings that while there was a statistical difference there was no educational difference between groups on recall or on problem solving. Any attempts with a learning technique would necessitate new or novel material, one of the assumptions made in developing the teaching-learning strategies.

4.6 SUMMARY

By using a canonical analysis it was found that there were relationships between the independent variables (Previous Knowledge, Developmental Level, Previous Achievement and Group membership) and the dependent variables (Recall and Problem Solving). However, the independent variables only accounted for 40% of the variance found in the Unit Test. Group membership was the primary influence on the Problem Solving section, the cognitive variables influencing Recall.

While the statistical analysis for the first hypothesis regarding recall indicated a statistically significant difference it was suggested that by rationally observing the actual differences between groups the results should be considered educationally non-significant. While there was a statistical difference found on problem solving between groups the mean scores indicated very little thought involved in answering the questions. It was also suggested that while the experimental group appeared to achieve higher scores the problem solving hypothesis should be considered educationally non-significant. On the variables of developmental level and previous achievement in science on Recall each factor made a statistically significant contribution to performance regardless of group membership.

In the final section the researcher's and teachers' logs were used to provide greater insight into the study. The Repeated Measures Test provided the basis for a discussion of the state of the students' previous knowledge of the subject matter even though it was apparently not part of any early curriculum they had been exposed to. An argument was presented that the assumption of no prior knowledge as specific as that found in the grade 9 curricuclum proved to be invalid. Previous work on learning strategies indicates that prior knowledge of the subject matter can be an interference variable. It is being suggested that the information found in this unit (Energy) has become "common knowledge" as the result of general public concern about Energy. Further, this general "common knowledge", while interferring with this study, has a greater message for science teachers in the Province. It is apparent from the teachers' responses that the assumption of no prior knowledge is held by them as well as the curriculum developers who have recently revised the grade 9 science text.

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 PURPOSE OF THE STUDY

The purpose of this study was to determine whether or not teaching-learning strategies, specifically taught for processing information, enhanced achievement in science at the grade 9 level. Based on an Information-Processing Model, it was hypothesized that these strategies would, overall, enhance recall and problem solving but, more specifically, interact with Developmental Level and Previous Achievement in science.

5.2 CONCLUSIONS

5.2.1 IMPLICATIONS OF THE STUDY ON RECALL

The results given in Chapter 4 suggest marginally superior performance on recall by the comparison group as opposed to the experimental group. It was anticipated that the teaching-learning strategies would enhance recall by providing the students with an efficient theory-based procedure for processing new information. As pointed out in Chapter 2 one of the apparent problems associated with new or novel information is how to manipulate it in such a way that it can be stored in a framework which allows for retrieval in a logical, coherent manner. That logical framework of information or schemata must be built up in long term memory. Then it must be labelled in a way that will allow a situation to stimulate an association with those lables. This will permit access to previously learned information. The teaching-learning strategies were based on identification of key labels and techniques specifically designed to reduce the amount of information into smaller units. They were also designed to place the onus of that information reduction and labelling on the student. While a schemata within memory may be an individual characteristic; i.e., between two people they may be similar they are not necessarily the same, there must be some uniformity in labels in order to stimulate the recall of that information otherwise there could be no common knowledge base for discussions. This is why key words, highlighted in the text, were emphasized and yet at the same time students were encouraged to use their own words to reduce large concepts associated with those words. The teaching-learning strategies were based on the theoretical rationale that by reducing the information into smaller units ideas can be learned and associations made through the repetition necessary to permit a concept to be stated in the smallest unit possible. By using the highlighted words in the text as the key labels for a concepy another practice effect would be expected since further work done with that text would require accessing previously learned concepts. This background would lead to the expectation that the teaching-learning strategies would enhance recall in the experimental group.

However, the evidence from this study points to the contrary: significant differences occured between the experimental and comparison groups, with the comparison group obtaining a higher mean recall score. This result was not anticipated from theory and led to an investigation of factors which might account for these results.

While the Information-Processing theory may be an overly simplified view of the classroom teaching-learning situation it is felt that this model provides a valid basis for attempting to describe the complex phenomenon of internalization and recall of information and that, therefore, theory should account for the unexpected results, other factors being equal. Klahr and Wallace (1976) have in a very detailed way shown how Information-Processing could be utilized in describing observed patterns of cognitive development. One aspect of this description is a division of the Long Term Memory into three tiers (with multiple levels), each dealing with: Tier I. Specific Experience, Tier II. Problem Solving Strategies, and Tier III. Production

Systems for Self-Modification. Further, the prime goals of the system are to provide efficiency through a self-regulatory process which detects consistencies (serial patterns) in the environment and eliminates redundancy. Within the above model it is possible to speculate on the results of this study with respect to recall.

When information is presented to an individual a search for relevant information is undertaken beginning within the first tier, Specific Experience. A move to the second tier, Problem-Solving Strategies, is made when "... the previous experience of the system has not given rise to consistent sequences" (Klahr and Wallace, 1976,p.186). Therefore, if there is no prior knowledge sequence on the topic a move will then be made to the second tier, Problem-Solving Strategies, which will be searched for a means to deal with this new information. These strategies would then provide a processing sequence to attempt to place the new information into memory. That processing sequence may be as simple as a mnemonic device or as complex as to provide some kind of pre-existing patterning device. Once a strategy is "chosen" the new knowledge sequence can be added to the first tier. If, however, there is a knowledge sequence already present in the first tier then the efficiency of the system precludes any need to search beyond this point.

As pointed out in Chapter 2, the search for a processing technique which will work for new information is often on a trial and error basis; therefore, it was felt that by providing the students with a processing technique instead of requiring a search for one there would be an increase in their ability to recall new information. In Chapter 4 arguments were presented to support the notion that while the Energy Unit is being presented by both teachers and curriculum developers as new material it apparently is not novel information to the students. Since this was probably the case it may be argued that a processing technique had already been found by the individual and the teaching-learning strategies were either redundant or ignored by the students. In Chapter 1 it was emphasized that the strategies would form a basis for processing information and that as a student matured he may find a more personal and efficient means for himself. In this case it is suggested that the basic processing provided by the teaching-learning strategies was not needed since the students apparently had already formed a knowledge base.

While the results of this study can be explained within the framework of the Information-Processing Model it also becomes necessary to peruse the findings from the instructional perspective of the classroom in order to attempt to account for the results. Within the natural environment of the classroom the variety of human judgement, motivations and personalities must be taken into account. It is possible that with the variety of teaching methodologies which the students are exposed to during a normal school day these experimental techniques were neither as intensive nor of sufficient duration to elicit the anticipated changes. For some students the rotating schedule sometimes allowed up to five days between classes. This coupled with the fact that the students were influenced by anywhere from 4 to 6 other teaching methodologies in a day may bring into question the effectiveness of the intensity of the treatment applied.

While two of the techniques, Summarizing (Brown, Campione and Day, 1980) and Written Questions and Answers (Andre and Anderson, 1978), produced positive results in previous research these studies were conducted under fairly controlled conditions, not in the classroom. Also, the intent of these strategies is similar to Concept and Vee Mapping (Novak and Gowin, 1985) which while showing positive results in some studies (see Chapter 4) when compared to outlining showed no statistically significant differences between High School groups on achievement in Science (Lehman, Carter and Kahle, 1985). Novak and Gowin (1985) feel that it would take a two year training period for the majority of students to correctly use the mapping techniques. This time factor was presented as one possible explanation for the results in the study by Lehman, Carter and Kahle (1985).

This might suggest that in this instance a time factor may have possibly been involved thereby making the teaching-learning strategies too subtle for both the time frame and the environmental conditions. However, these particular strategies were chosen because of their simplicity and the ease with which they could be incorporated into a pre-existing pattern within the classroom. Sometimes the complexity and novelty of a technique masks the intent of the exercise; thereby, producing ambiguous results.

It is also possible that any improvements were masked by group membership. This should be taken into consideration especially since two of the experimental teachers felt that there were observable improvements in specific students. For example, the least able student who ended up with the highest Posttest grade in the class or the students who provided unsolicited comments about using the strategies in other classes. Also, a student who might be more attentive on a one-to-one basis has more opportunity to be less attentive and thereby loose some of the intensity of the treatment when he becomes part of a group. The potency of a treatment, of any kind, is a reflection of an individual's personality and background. It becomes speculative whether or not these strategies were of a low intensity or complicated by other factors. With the background information regarding the type of individuals composing the classes provided in Chapter 4 it is being suggested that the marginally statistically significant difference in recall was a function of the students' personalities;i.e., the students in the comparison group were more conscientious and diligent in their academic work and appeared to be "better" students than the other students in the study. Since there were no statistically significant differences between groups on the Pretest results it would be expected that students who are considered better workers would perform better on the Posttest simply because of their work habits, all other qualities being equal.

Also, there were no statistically significant differences between teachers within the experimental group or within the comparison group it would be difficult to understand no differences in personality between the teachers involved. It was anticipated that some variability would occur and become evident in the statistical results and yet none was found. Other factors such as rotating schedules, extracurricular influences, selectivity of groups, and so on would lead one to expect differences. Yet, statistically the variability of responses of 311 students was not great enough to point out a problem with any of the testing instruments. Again, this is interesting considering the diversity expected from 311 individuals.

While the results of the study can be explained within the contexts of the Information-Processing Theory an attempt has been made to analyze the factors outside of the model which influence teaching and learning within the classroom. Even though any of the above factors alone or in combination may have resulted in the findings on recall it is felt that the most logical answer and one which is consistent with the Information-Processing Model is the hindering effect of previous knowledge.

5.2.2 IMPLICATIONS OF THE PROBLEM-SOLVING STUDY

The evidence reported in Chapter 4 indicates a statistically significant difference between the two groups with the experimental group obtaining a higher mean score. It was anticipated that the teaching-learning strategies would enhance problem solving by providing a schemata for new information which could be manipulated to provide answers to problem questions. It was expected that the schemata of new information would provide a knowledge base which could be used to explain situations or answer questions. By using this new knowledge it would mean that not only was the information learned on a recall basis but that it could be manipulated in different situations.

While the expected results were obtained on the problem solving section of the Posttest the overall score was less than one complete answer correct. As mentioned in Chapter 4 the SOLO Taxonomy provides coding which will identify incomplete or incorrect answers. This coding has produced scores with means of less than one correct answer for both the experimental and comparison groups. Therefore, while the results were statistically significant for the experimental group it is suggested that no educational significance is actually apparent between groups.

Since the teaching-learning strategies were attempting to provide further resources to the problem solving tier and using the Information Processing Model of Klahr and Wallace (1976) it was apparent that any previous knowledge would be an interference and hinder that effort As pointed out in Chapter 4, the students already appeared to have a common knowledge base on the topic which also overrides the new information presented in class. This again is consistent with the Information-Processing Model which shows that a build up of information on a previous knowledge base will interrupt and stop the processing within a tier thereby preventing a need to move to the problem solving tier.

Since the test was limited in time and the problem-solving portion of the test limited to description in the form of an essay it is suggested that what was actually reported was the first part of the knowledge base which would answer the question rather than moving to the problem-solving tier. The answers given were often something other than the material covered in class thereby suggesting a knowledge base obtained outside of the classroom. As deBono (1982) points out, students will respond to questions with the lowest level answer which they feel is correct rather than risking a more thoughtful answer which may be incorrect. In order for the teaching-learning strategies to become effective it would be necessary to present information for which there was no adequate knowledge base thereby requiring a move to the second tier, problem-solving strategies. Also, because of the results a concern as to the construct validity of the problem solving portion of the test might be raised. With such an overall poor performance from both groups, despite the statistical results, what might have been tested was the students' writing skills. Since the teaching-learning strategies required considerable writing practice it is suggested that the findings were more the result of practice obtained in writing rather than an increase in problem solving ability.

5.2.3 IMPLICATIONS OF THE INTERACTION STUDY

The results given in Chapter 4 suggest no interaction between group membership and either Developmental Level or Previous Achievement in Science. It was anticipated that the teaching-learning strategies would interact with Developmental Level and Previous Achievement in such a way that those students who were at a lower Developmental Level or were poor academic students would receive the most benefit. As students mature they not only increase the number of processing strategies available to them but they also become more aware of them in terms of matching a strategy to a situation. Also, a student who does not process new information correctly tends to forget or not remember efficiently enough to perform well on tests.

The statistical results showed no significant differences in either interaction, Developmental Level or Previous Achievement with recall and problem solving. Students who were at a higher Developmental Level or academically better students performed better on the Posttest. Those students at a higher developmental level probably were already aware of strategies to use with scientific information and perhaps found the strategies redundant or not useful to them, in which case they performed the assignments while also utilizing their own techniques. Students who perform well academically often tend to do so no matter which teaching methodology they are exposed to. While it has been shown in a variety of studies that specific mthodologies enhance achievement of students with specific characteristics there are a number of students who perform well despite the teaching technique used.

As mentioned before, the influence of any previous knowledge about a subject can interfere with the study in such a way as to prevent clear cut answers. When these results are viewed within the results of this study with respect to main effects it is apparent that the tests for any interactions are inconclusive.

5.3 RECOMMENDATIONS

The results of this study fall into two categories: those results which answer the questions asked and those results which raise further questions and concerns.

It would not be warranted to attempt any definitive statements about changes in achievement (increases or decreases) with the use of these teaching-learning strategies based on the results of this study. However, this study has pointed out some of the factors which must be taken into account in any further research with these materials.

1. It is recommended that these materials be used in another science classroom study where previous work has been done on prior knowledge to control for this influencing factor. Perhaps at the grade 8 level where students are beginning a more formal study of science. But even here prior knowledge must be considered since assumptions should not be made based on a curriculum review alone.

2. These materials might also be used again in a study where comparisons could be made on an individual basis rather than within a group. The achievement of a group masks individual variability. This was seen in one experimental group where a student with a low grade ended up with the highest post-test score for the group.

3. Also, it might be advantageous to conduct this study with greater controls than those in the classroom setting. However, an increase in the amount of controls may interfere

with the reliability of results if the intended population is a average classroom of students.

4. As a final suggestion the influence of risk associated with a test when attempting to measure problem solving ability could be reduced by conducting a type of "creative essay" on a particular problem within a class period rather than in a formal, graded testing situation.

Of further interest is the suggestion that these grade 9 students were apparently already aware of this knowledge. Several concerns on a higher level emerge from this, especially if the Province is moving toward mandatory Provincial Exams: If they already know the information in the Energy Unit 1. How much of the rest of the curriculum do they know? 2. Should as much classroom time be spent on this Unit? 3. What ramifications would these questions have on the curriculum in general and on supplimental materials? 4. What do these results mean to a teacher with regard to government exams and their subsequent interpretation?

All of these questions go beyond the scope of this present research. However, it is recommended that these concerns be addressed through further study.

5.4 UTILITY OF THE STUDY

With respect to this study and these particular questions, and based solely on the opinions of the teachers and students involved, the teaching-learning strategies were useful and easy to employ. They were convenient to implement and apparently placed no extra burden on the teachers, in other words they were "cost effective". This is a critical point for any classroom teacher. These strategies may also provide the teachers with an alternative to the traditional assignment usually given at the junior high school level. In a meta-analysis done on studies identifying the relationship between science achievement and science attitudes, at the junior high school level, interest was more highly related to achievement than either attitude or behavior (Wilson, 1983). If these strategies provide a certain amount of variety for the student, especially if the content is known to him, then there is a utility for the teacher and student beyond achievement.

By looking at the problem solving section, the teaching-learning strategies apparently increase a student's ability to express himself on paper by "forcing" the student to practice writing in science class. For many teachers this alone may be a benefit. Concise and accurate reporting and expression of ideas is even more critical in science than in other fields and yet there is very little built-in practice of this art within science classes.

While a model is changed and adapted to the permutations found in human endeavors there should also be that reciprocal development of techniques based on the model. In attempting to do this the present study has encountered and focussed on a few select extraneous variables which prevented the type of clear cut answers one expected by functioning within the parameters of a model. This by no means negates the model but rather emphasises the need for more research with materials based on the model. Models must change to meet reality but only with sufficient evidence. A distinction must be made between those who theorize within education and, as Lin (1979) proposes, those educational engineers who use a theory within the practical realm of the classroom. This study was such an attempt.

If enhancing the capabilities of a student is important then attempts must be made to apply theory based strategies within natural classroom settings. Although, further research must also be undertaken with a focus on the changing knowledge base of students. While attempts were made to control for previous knowledge (the Pretest) it became apparent that this effort was not enough and that previously learned knowledge about Energy prevented clear answers to the questions posed. However, the teaching-learning strategies appear to have a place in grade 9 science and a value for both teachers and students. This value is found in their clarity and utility, as well as in the emphasis placed on the student to be responsible for his own learning. A teacher must present the information and provide the opportunity for the student to learn, which was the intent of the teaching-learning strategies. But no matter how much information is presented by the teacher, only the student has the capacity to internalize the material. Through further refinements and research with these strategies as a base perhaps a series of techniques can be developed to guide a student into a personalized system for learning to learn.

BIBLIOGRAPHY

Andre, Marli and Thomas A. Anderson. "The Development and Evaluation of a Self-Questioning Study Technique". Technical Report No. 87, University of Illinois at Urbana-Champaign, June 1978.

Arlin, Patricia Kennedy. "A Multitrait-Multimethod Validity Study of a Test of Formal Reasoning".*Educational and Psychological Measurement* ,Win 1982,42(4), 1077-1088.

Arlin Test of Formal Reasoning. East Aurora, New York:Slosson Educational Publications, Inc., 1984.

Baker, Linda and Ann L. Brown. *Metacognitive Skills and Reading*. Technical Report No.188, Center for the Study of Reading, University of Illinois, Nov.1980.

Biggs, John B. *Cognition, Development and Instruction*. John R. Kirby and John B. Biggs (Eds.) New York:Academic Press, 1980.

Biggs, John B. and Kevin F. Collis. *Evaluating the Quality of Learning the SOLO Taxonomy*.New York:Academic Press, 1982.

Biggs, John B. and John R. Kirby. "Emergent Themes and Further Directions", *Cognition, Development, and Instruction*. John R. Kirby and John B. Biggs, Eds.New York:Academic Press, 1980.

Bloom, Benjamin S. *Human Characteristics and School Learning*. New York:McGraw Hill Company, 1976.

British Columbia Junior Secondary Science Curriculum Guide and Resource Book. Ministry of Education, British Columbia, 1984.

British Columbia Science Assessment. General Report to the Ministry of Education , Learning Assessment Branch, British Columbia, Hugh Taylor (Ed.), Sept. 1982.

British Columbia Science Assessment. General Report to the Ministry of Education, Learning Assessment Branch, The Science Assessment Contract Team, October 1978.

Brophy, Jere E. "Teacher Behavior and Its Effects", *Journal of Educational Psychology*, 1979, 71(6), 733-750.

Brown, Ann L. and Craig R. Barclay. "The Effects of Training Specific Mnemonics on the Metamnemonic Efficiency of Retarded Children",*Child Development*, 1976,47,71-80.

Brown, Ann L., Joseph C. Campione, and Jeanne D. Day. Learning to Learn: On Training Students to Learn From Texts, Technical Report No.189. Paper presented to American Educational Research Association, Boston, Mass., April, 1980.

Brown, Ann L. and Judy S. DeLoache. "Skill, Plans, and Self-Regulation", Children's Thinking: What Develops?. Robert S. Siegler, Ed. Hillsdale, New Jersey:Lawrence Erlbaum Associates, 1978.

Camperell, Kay. Other to Self-Regulation: Vygotsky's Theory of Cognitive Development and Its Implications For Improving Comprehension Instruction for Unsuccessful Students. Paper presented at the Second Annual Meeting of the American Reading Forum. Sarasota, Fla., Dec., 1981.

Case, Robbie. The Process of Stage Transition in Cognitive Development. Final Report: National Institute of Child Health and Human Development, September, 1977.

Case, Robbie. "Intellectual Development from Birth to Adulthood: A Neo-Piagetian Interpretation", Children's Thinking: What Develops? Robert S. Siegler, Ed. Hillsdale, New Jersey:Lawrence Erlbaum Associates, 1978.

Cavanaugh, John C. and Marion Perlmutter, "Metamemory:A Critical Examination", Child Development, 1982, 53(1),11-28.

Census of Canada, 1981. Selected Social and Economic Characteristics B.C. Ministry of Supply and Services Canada, July, 1983.

Chi, Michelene T. "Knowledge, Structures and Memory Development",Children's Thinking: What Develops?" Robert S. Siegler, Ed. Hillsdale, New Jersey:Lawrence Erlbaum Associates, 1978.

Cohen, Gillian. The Psychology of Cognition. New York:Academic Press, 1977.

Cook, Thomas D. and Donald T. Campbell. Quasi-Experimentation:Design and Analysis Issues for Field Settings. Boston:Houghton Mifflin Co., 1979.

Dirkes, M. Ann. Divergent Production Stimulates Learning and Transfer. Paper presented at the 88th Annual Convention of the American Psychological Association, Montreal, Sept. 1980.

Doyle, Walter. "Academic Work", Review of Educational Research, Summer 1983,53(2), 159-199.

Doyle, Walter. "Classroom Tasks and Students' Abilities", Research on Teaching: Concepts, Findings, and Implications. P. Peterson and H. Walberg (Eds.), Berkley, Calif.:McCutchan Publishing, Corp., 1979.

Dunkin, Michael and Bruce Biddle. The Study of Teaching. New York: Holt, Rinehart and Winston, Inc. 1974.

Eylon, Bat-Sheva. Effects of Knowledge Organization on Task Performance. Unpublished doctoral Dissertation. Berkely, Calf.:University of California, 1979.

Fisher, C., D. Berliner, N. Filby, R. Marliave, L. Cahen and M. Dishaw. "Teaching Behaviors, Academic Learning Time and Student Achievement: An Overview", in Time To Learn, Carolyn Denham and Ann Lieberman (Eds.) National Institute of Education, 1980.

Gagné, Robert. "Learnable Aspects of Problem Solving",Educational Psychologist, 1980,15(2),84-92.

Good, Thomas L. "Teacher Effectiveness in the Elementary School", Journal of Teacher Education, 1979,30(2),52-64.

Gowin, D. Bob. Educating. Ithaca, N.Y.:Cornell University Press, 1981.

Greeno, James G. "Natures of Problem-Solving Abilities" in Handbook of Learning and Cognitive Processes: Human Information Processing (Vol. 5). W.K. Estes (Ed.), Hillsdale, New Jersey: Lawrence Erlbaum Associates, 1978.

Groen, Guy and Lauren B. Resnick. "Can Preschool Children Invent Addition Algoritms?" Journal of Educational Psychology, 1977,69(6),645-652.

Handley, Herbert M. and Linda W. Morse. "Two-Year Study Relating Adolescents' Self-Concept and Gender Role Perceptions to Achievement and Attitudes Toward Science", Journal of Research in Science Teaching, Sept. 1984,21 (6), 599-607.

Huhn, Ralph H. RSM2P:A Metacognitive Approach for Teaching Cognitive Strategies to Facilitate Learning. Paper presented at the Annual Meeting of the American Reading Forum, Longboat Key, Fla., Dec., 1981.

Janzen, Henry L. "The Development of Informaton-Processing and Set Patterns in Elementary School Children:Some Practical Application",School Psychology International, 1981,2(1),28-30.

Kirk, Roger E. Introductory Statistics. Monterey, California:Brooks/Cole Publishing Co., 1978.

Koran, Mary Lou and John J. Koran. "Aptitude-Treatment Interaction Research in Science Education", Journal of Research in Science Education, 1984,21(8),793-808.

Lawson, Michael J. "Metamemory: Making Decisions About Strategies", Cognition, Development and Instruction. John R. Kirby and John B. Biggs (Eds.) New York:Academic Press, 1980.

Lehman, James D., Charlotter Carter and Jane Butler Kahle. "Concept Mapping, Vee Mapping, and Achievement: Results of a Field Study with Black High School Students", Journal of Research in Science Teaching, 1985, 22(7), 663-673.

Levine, Mark S. Canonical Analysis and Factor Comparison. Series: Quantitative Applications in the Social Sciences. London: Sage Publications, 1977.

Loftus, Geoffrey R. and Elizabeth F. Loftus. Human Memory: The Processing of Information. Hillsdale, New Jersey:Lawrence Erlbaum Associates, 1976.

Murphy, Maureen T. and Manfred C. Schmidt. Developing Science Concepts in the Laboratory. Scarborough, Ontario: Prentice-Hall, Ltd., 1979.

Newell, Allen and Herbert A. Simon. Human Problem Solving. Englewood Cliffs, N.J.:Prentice-Hall, Inc., 1972.

Novak, Joseph D. "An Alternative to Piagetian Psychology for Science and Mathematics Education", Science Education, 1977, 61 (4), 453-477.

Novak, Joseph D. and D. Bob Gowin. Learning How to Learn. Cambridge :Cambridge University Press, 1984.

Novak, Joseph D., D. Bob Gowin and Gerard T. Johansen. "The Use of Concept Mapping and Knowledge Vee Mapping with Junior High School Science Students", Science Education , 1983, 67(5), 625-645.

Norman, Donald A., Donald R. Gentner, and Albert L. Stevens. "Comments on Learning Schemata and Memory Representation",Cognition and Instruction. Hillsdale, N.J.:Lawrence Erlbaum Associates, 1976.

Pedhazur, Elazar J. *Multiple Regression in Behavioral Research*. New York: Holt, Rinehart and Winston, 1984.

Peterson, P.L. and Susan R. Swing. "Beyond Time on Task: Students' Reports of Their Tought Processes During Classroom Instruction" *The Elementary School Journal*, 1982, 83(5),481-491.

Pieper, Charles John and Wilbur Lee Beauchamp. *Everyday Problems in Science*. Toronto:W.J. Gage & Co. Ltd., 1936.

Resnick, Lauren B. "Task Analysis in Instructional Design: Some Cases rom Mathematics",*Cognition and Instruction*. David Klahr, Ed. Hillsdale, N.J.:Lawrence Erlbaum Associates, 1976.

Resnick, Lauren B. and Wendy W. Ford. *The Psychology of Mathematics for Instruction*. Hillsdale, N.J.:Lawrence Erlbaum Associates, 1981.

Science Council of Canada. *Background Study 52: Science Education in Canadian Schools*. by Graham W.F. Orpwood and Jean-Pascal Souque, Quebec: Canadian Government Publishing Centre, 1984.

Siegler, Robert S."The Origins of Scientific Reasoning",*Children's Thinking: What Develops?* Robert S. Siegler, Ed. Hillsdale, N.J.:Lawrence Erlbaum Associates, 1978.

Simon, Herbert A. "Information-Processing Theory of Human Problem Solving" in *Handbook of Learning and Cognitive Processes: Human Information Processing (Vo. 5)*. W.K. Estes (Ed.), Hillsdale, New Jersey: Lawrence Erlbaum Associates, 1978.

Snedecor, George W. and William G. Cochran. *Statistical Methods*. Ames Iowa: The Iowa State University Press, 1980.

Staybrook, Nicholas, L. Corno and P. Winne. "Path Analyses Relating Student Perceptions of Teacher Behavior to Student Achievement", *Journal of Teacher Education*, March-April 1978, 29(2), 51-56.

Tobias, S. "Achievement-Treatment Interaction", Review of Educational Research, 1976,46,61-74.

Winne, Philip H. and Ronald W. Marx. "Students' and Teachers' Views of Thinking Processes for Classroom Learning", The Elementary School Journal, 1982, 82(5), 493-518.

APPENDIX A

PART I: INFORMATION GIVEN TO ALL TEACHERS

INTRODUCTION

This research study deals with a comparison between two experimental groups. Both groups consist of five teachers with their respective classes of grade 9 students. All ten teachers will be following the same topic outline on the Energy Unit which they helped to develop. The difference being tested is on one aspect of the tasks students are assigned. This study has NO control group. Therefore, certain internal controls have been established to account for this missing factor.

Due to the fact that there are two experimental groups it was deemed necessary to provide each teacher with a specific amount of information as a control procedure. Each teacher is being asked to use discretion in discussing the project since this may compromise the results and subsequent interpretation of the study. It is hoped that each teacher will understand this request. After the analysis has been completed, all teachers involved in the study will be given the results as well as a packet containing a complete set of all materials used in the study.

It is important for the teachers involved to understand the necessity for adherence to the topic outline and recording the completed tasks as well as keeping the daily log. Every effort has been taken to try to prevent "teacher proofing" the outline. The individual nuances and variety which a teacher brings to his presentation are as important as the material, and in some instances even more important.

This is why references are made to a topic outline. The chapters listed are simply to provide an easy reference to the topics being covered. Each teacher must use his own judgement when considering the breadth of a topic presentation.

Within the constraints placed on teachers by this study it is hoped that the classes will be conducted as close to normal as possible. Students should NOT be aware that anything is unusual or different. For this study to have any meaning to the average classroom teacher the situation must be as realistic as possible. Therefore, this research is being conducted with as many controls as possible while at the same time trying not to interfere with the normal functioning of the classroom.

GENERAL POINTS TO NOTE

1. Make sure the students know that assignments will be marked.
2. Emphasize the importance of keeping a notebook. Discuss the utility of studying from class notes and assignments while using the text only for clarifying points.
3. Make sure all assignments are corrected.
4. Make sure you go over the assignments in the next class meeting or at the earliest convenient time.
5. Mark the assignment for completeness on the Assignment Record.

DAILY LOG

DATE

CLASS/BLOCK

TOPIC OF THE LESSON:

HOMEWORK ASSIGNED

DID YOU CORRECT A PREVIOUS ASSIGNMENT?

IF YES, WHICH ONE?

COMMENTS:(Please include any extraneous events which may have affected your class.)

DATE

CLASS/BLOCK

TOPIC OF THE LESSON:

HOMEWORK ASSIGNED

DID YOU CORRECT A PREVIOUS ASSIGNMENT?

IF YES, WHICH ONE?

COMMENTS:(Please include any extraneous events which may have affected your class.)

SCHEDULE SUMMARY

N.B. All testing materials will be supplied to you.

PERIOD	TOPIC
1	Introduction
2	Pretest (probably less than 1 period)
3	Introduction
4	Arlin Test of Formal Reasoning (approximately 1 period)
5-6	Chapter 1
7-9	Chapter 2
10-11	Chapter 3
12-14	Chapter 4
15	Test
16-17	Chapter 5
18-20	Chapter 6
21-23	Chapter 7 and 9
24	Final Test

CATEGORIES FOR THE CODING OF ESSAY ANSWERS

The following criteria are used to categorize essay answers. These categories do NOT represent a grade, but rather are numerical codes to inidicate the complexity of the students' answers. After each category an example has been provided. A history example was chosen rather than one from science since it becomes obvious when the student begins to use deductive reasoning; whereas, in science, much would depend on exactly what had been taught in class. (Specific references will be provided at the end of the study.) An additional set of categories has been provided to accomodate those answers which do not fit "nicely" into a specific area. This allows an "in-between" categorization. Background for the example:

Grade 9 students were given a lesson on squatters in Australia as part of a history lesson. They were then asked, "What reasons did the squatters have for defying the government's regulations? Were they justified?"

CATEGORY 1

1. avoids the question, refuses to answer or simply guesses.
2. repeats or restates the question.
3. makes an irrelevant, personally based association.

Example: "None. They defied the government."

"They were justified, but many of the squatters were quite wealthy anyways."

CATEGORY 1A

* inadequately uses potentially relevant information but only partially grasps a significant point.

CATEGORY 2

1. selects 1 relevant aspect from the evidence and correctly answers with that.

Example:

"Yes, because they were helping to develop the wool industry."

CATEGORY 2A

* selects 2 relevant aspects that are inconsistant or unrelated and, therefore, draws no firm conclusion from them.

CATEGORY 3

1. selects 2 or more relevant points from the evidence but ignores any inconsistencies and makes no integration or connection .
2. facts are written as isolated points with no relationship given, no firm conclusion is reached. For example: "... and ... and then ... and also".

Example:

"Yes, the squatters were justified because there was better pasture land outside the limits of location and another reson was that the wool industry would grow."

CATEGORY 3A

* recognizes inconsistencies but is unable to resolve them, or makes only a partial integration of the facts.
* attempts to draw a conclusion, although it may be wrong.

CATEGORY 4

1. uses all or most of the relevant information and integrates it with a relating concept, reconciling any conflict but remaining within the given context.
2. the conclusion drawn may be invlaid outside of the specific context of the question.

Example:

"No. I don't think the squatters were justified because although the price of land was too high and they did not have enough security and it was wrong to go and just take over the land without permission; laws are made to be kept by the public."

CATEGORY 4A

* recognizes the relativity of the explanation, but inadequately makes use of abstract principles that override context. Attempts to use an abstract idea but uses it incorrectly.

CATEGORY 5

1. uses abstract principles that show the example is just one of many possible results or explanations.
2. uses deductive reasoning from the information.
3. no firm decisive answer, shows that the outcome may be different with other data or in another context.
4. appeals to hypothesis and to examples not given in the original, uses analogies compatable with the principle.

Example:

"It depends on how wide a term you want justified to be. In a restricted sense you could say that the squatters were not justified because the Government saw a need to develop and focus its resources in a known rather than an unknown area. If you widen the term, you can say that the squatters felt themselves to be justified, since they had emigrated largely so that they could own land. When they arrived they found that the land was too expensive so they 'squatted' on it and by hard word and occupancy, felt they had made the land their own. Taking an even wider view the squatters were justified beause in a long term, the wealth of the Austra[il]an colonies rested on the productivity of the squatters."

PART II. INFORMATION GIVEN ONLY TO THE EXPERIMENTAL TEACHERS

RATIONALE

From the work done in Human Development, Problem Solving and Information Processing it has been found that as learners mature they develop a wide variety of means for handling information presented to them. The student develops, through trial and error, a repertoire of personally useful strategies or techniques which he imposes upon situations. This allows the student to identify important or useful information and to store it in a manner which provides appropriate retrieval. However, when the information being presented is new or unfamiliar students tend to become novice learners again, attempting various procedures, until some means for processing that information can be found. A brief background summary from the literature is provided at the end of this booklet.

Science appears to be a good example of a subject which introduces new and often unfamiliar terminology and concepts. If the student resorts to a technique which may have worked in other situations, but not work in science, he may encounter failure to comprehend the material or to retain it. By the time the student has hopefully worked out a means for processing the information a great deal of factual material may already be lost to him due to the progression of the class or the addition of new topics. This is exemplified by the student who does not perform well on a test and yet insists that he studied for it. When questioned further he will explain how long he had studied with no thought as to how he studied.

It is being suggested that one possible means of alleviating this problem may be to provide the student with explicit directions for processing information. However, simply describing a technique is not enough for a student, it must be demonstrated and then practiced. It is with this basic rationale that the following four study techniques are being tested.

PROCEDURE

The four study techniques being presented are based on Information Processing Theory and are designed to provide a means for increasing the amount of scientific information learned and retained by the students. Each technique has specific directions for its use, an example for demonstration, and is taught prior to an assignment for practice. The first time an assignment is given it should be practiced in class, if possible. Suggestions for implementation are given; however, it is anticipated that teachers will personalize the presentation. It will require a certain amount of perserverence and patience in the beginning until the students become comfortable with the format of the work.

It is important that the students be aware that the assignments are to help them understand the material better by providing a study technique. Explain the purpose of the assignment to them. These assignments are to be an aid to the student and teacher and should not become a focal point of the class. It is suggested that the tasks initially be demonstrated and perhaps practiced in class to assure you that the students understand the study procedure. When you are confident that the procedure has been learned, the tasks may be assigned as homework. It is important that all work MUST be corrected or gone over in the next class period, excluding lab time.

As the students familiarize themselves with the techiques some variations may begin to occur in the assignments. Please make note of these. It will be necessary for you to judge whether or not the variations should be corrected. Since this study is being based on these four particular techniques adherence to the directions is necessary for evaluation purposes. An Assignment Record is provided to document the amount of each assignment attempted (this is NOT a grading sheet but rather will give some idea of how much work the student tried to do).

A consideration which must be emphasized to the student is the necessity of using his own words and thoughts. Copying from a book tends to become a very mechanical process requiring little mental involvement.

As the student progresses through a chapter the assignments have allowed him to keep a section-by-section summary, in various forms, so that before at test most of the studying will be done from the set of assignment sheets for each chapter. Reviewing should be done with the summaries and diagrams. A student will need to learn to test himself using the vocabulary sheet and answer the questions he has written. The textbook should then become a reference source for material not learned or misunderstood.

General Points to Note

1. Make sure the students know that assignments will be

marked.

2. Have patience - it may take a few times practicing the technique before they completely understand.
3. Emphasize the importance of using their own words.
4. Emphasize the importance of keeping a notebook. Discuss the utility of studying from the assignment sheets and class notes while usingthe text only for clarifying points.
5. Make sure all assignments are corrected.
6. Make sure you go over the assignments in the next class meeting or at the earliest convenient time.

General Instructions

1. Review the instructions with the students.
2. Go over the example provided.
3. Give the first practice assigment.
4. Review the assignment the next day with the class.
5. Mark the assignments for completeness on the Assignment Record.

VOCABULARY LIST

Directions

Divide a sheet of paper into three columns. Write the study word in column 1. Then briefly define or desribe the word in column 3. When you are ready, and you think that you know the definitions, cover column 3 or fold it to the back. Fill in the definitions or descriptions in column 2. Mark the ones that you got wrong by comparing columns 2 and 3.

RULES

1. Make sure you use your own words. Try not to copy directly from the book.
2. You may add words or phrases that are not highlighted if they are important to you.
3. Keep within the space provided. Remember, it is important to shorten the wording without losing the meaning.
4. You are looking for key words and phrases. Your textbook generally will highlight all new and important terms.

EXAMPLE

Using the paragraph from the Summarizing Sheet, set up a Vocabulary List for the important terms or ideas.

NEW WORDS	DEFINITIONS	DEFINITIONS
metre		unit of length
Newton		unit of force
N		symbol for Newton
Sir Isaac Newton		force unit named after him,British scientist

SUMMARIZING A READING

RULES

1. Write a sentence describing the main idea of the paragraph or reading. Try to use as many of your own words as possible.
2. Eliminate any unnecessary material. Mentally cross it out.
3. Select a topic sentence or sentence containing a key idea and underline it (if possible). Your book highlights key words - these are important.
4. Cluster items if possible. For example; cats, dogs, horses, and cows can all be called animals.

Remember : the idea is to reduce the number of words without losing ideas.

EXAMPLE

ASSIGNMENT : Briefly summarize the following paragraph.

When we want to measure the length of an object we can find out how many metres long it is. We say that a metre is a unit of length . When we want to measure how much force is exerted on an object, we find out how many newton are exerted. Just as a metre is a unit of length, a newton is the unit of force . The symbol for newton is " N ". It is named after a British Scientist, Sir Isaac Newton (1642-1727) who made many important discoveries.

SUMMARY : A metre is a unit of length while a newton (N) is a unit of force. The newton is named after the late 17th century British scientist, Sir Isaac Newton.

WRITING QUESTIONS AND ANSWERS

RULES

1. Ask a question about the major or key ideas in the reading. Use the same rules as in Summarizing.
2. Answer the questions by expanding the idea rather than just repeating the question in a different way.
3. Do not use the questions in the book. Try to ask your own questions.

EXAMPLE

Write one question from the reading on page 14, then answer it.

Question: How would you know if an Energy transformation occurred?

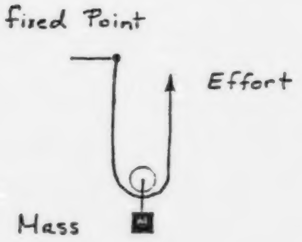
Answer: In a lot of cases you could use your senses to know that an energy transformation has occured: as in, heat from burning gas, light from a bulb, sound from a radio or watching a book fall

DIAGRAMMING AND SIMPLIFYING

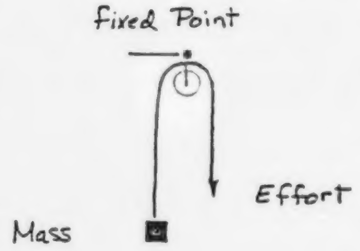
RULES

1. Keep in mind the rules for summarizing. Eliminate any unnecessary information.
2. Use stick figure drawings.
3. Like a newspaper cartoon, keep everything short and simple.
4. Label only important parts. Identify only key phrases or formulas. EXAMPLE

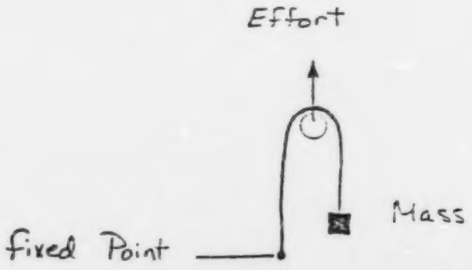
Diagram and label the pulley systems in 1-1 on page 48.


Fixed Point
Effort
Mass

Movable Pulley
Effort Advantage


Fixed Point
Effort
Mass

Single Stationary Pulley
Advantage is in pulling
things up to any height


Effort
Mass
Fixed Point

Speed Advantage

HEAT OUTLINE

TIME: 2 PERIODS

CHAPTER 1 What is Energy?

1-1 Why Study Energy?

1-2 Energy and Its Forms

Vocabulary List - all new words.

(The first two sheets need to be handed out together.)

1-4 Energy Transformations

1-5 Potential and Kinetic Energy

Summarize pages 14 and 16.

1-3 Investigation: Using Various Forms of Energy

Demonstration - Procedures: Part 1,3,4,6,7. Parts 2 and 5 discussion. Answer all italicized questions under each part as well as page 13, questions 1-4.

TIME: 3 PERIODS

CHAPTER 2 Forces

1-7 What is a Force?

Vocabulary List - all new words.

1-9 The Force of Gravity on a Mass

Write 3 questions and answer them.

1-11 What Causes Friction?

Summarize each type of friction.

Write a question and answer for each.

1-8 Investigation: Measuring Forces

Answer all italicized questions. Page 22, questions 1 and 2.

1-10 Investigation: What is Friction?

Procedures: Part 1 (include D), Part 2, Part 3 and Part 4. Answer all italicized questions under each part. Page 27-28, questions 1,3,4,7,11.

TIME: 2 PERIODS

CHAPTER 3 Work: A Measure of Energy

1-13 Measuring Energy

Vocabulary List - all new words.

Summarize. Write 2 questions and answer them.

1-14 Investigation: Calculating Work and Energy

Procedures: A through I. Answer all italicized questions. Pages 43-44, questions 1,5,10,11.

TIME: 3 PERIODS

CHAPTER 4 Simple Machines

1-16 What is a Simple Machine?

Vocabulary List - all new words.

Summarize the reading.

1-19 Common Simple Machines

Diagram and label each type of simple machine. Ask one questions and answer it for each of the six types.

1-17 Investigation: Pulleys

Procedures: Part 1,2,3 (omit 4 and 5). Answer all italicized questions. Page 51, questions 1,2,4.

1-18 Investigation: Levers and Screws

Procedures: Part 1,2,3. Answer all italicized questions. Page 57, questions 1 and 5.

TEST

TIME: 2 PERIODS

CHAPTER 5 Factors That Determine a Change in Motion

1-22 Accelerating and Decelerating

Vocabulary List - all new words.

1-25 The Importance of Inertia

Summarize. Write and answer 3 questions about the reading.

1-23 Investigation: Balanced and Unbalanced Forces

Procedure: A-F (omit G). Answer all italicized questions. Page 74, questions 1a,b,c and 2a,b,c.

1-24 Investigation: Observing Inertia

Procedure: A,B and D (omit C). Answer all italicized questions. Page 77, questions 3a,b,c and 6a,b,c,d.

TIME: 3 PERIODS

CHAPTER 6 The Law of Conservation of Energy and Energy Converters

1-28 The Law of Conservation of Energy

Vocabulary List - all new words

Summarize the reading.

1-31 The Power of an Energy Converter

Write 2 questions and answer them.

1-29 Investigation: Energy Converters

Procedure: Part 1 Demonstration A-F (omit E), include the concept of efficiency but not the formula. Answer all italicized questions. Part 2 - G. Page 89, questions 1,2,5,11,12.

1-32 Investigation: Measuring your own Power

Procedure: Parts A-I. Page 97-98, questions 1,4,5.

TIME: 3 PERIOD

CHAPTER 7 Heat Energy

1-34 Heat Energy and Energy Transformations

Vocabulary List - all new words

Summarize each transformation.

1-36 The Energy of Particles

Write and answer 1 questions.

CHAPTER 9 The Transfer of Heat Energy

1-47 What Happens to Heat Energy

Summarize

1-48 Investigation: Conduction

Demonstration. Procedure: Part 1 A-G (omit Part 2). Page 146, questions 2a,b,c,d; 3a,b; 7a,b,c; 13a,b.

1-49 Investigation: Convection

Demonstration. Part 1 A-C (discuss Part 2). Page 151, questions 3a,b; 4; 8a,b,c.

*1-50 Investigation: Radiation of Infra-red Rays

Discuss concepts.

Page 157, questions 3a,b; 12a-f.

1-51 What Happens When Heat Energy Is Transferred

Write 2 questions and answer them.

1-52 Infra-Red Radiation

Summarize each of the 3 sections.

1-53 Insulation

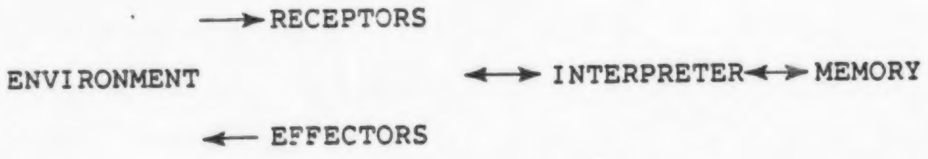
Write 2 questions and answer them.

BACKGROUND SUMMARY

The following selected summaries are from the literature on Information Processing, Problem Solving and Human Development. In trying to give you a brief background a great deal of information has been omitted; but, hopefully this will provide a broader rationale for viewing this study

Information Processing

The information-processing system is an abstract representation, providing a model which shows the selection, acquisition, and utilization of information. This model is useful since it provides a means by which we can discuss what happens to information when it has been presented to a person. The model is as follows:



This provides an interface between the environment, with a receptor of stimuli and an effector of responses to that stimuli. These two aspects of the system are the basic sources of all incoming and outgoing activity of the individual. At the base of the receptor and effector systems lies the interpreter, also known generally as short-term memory (abbreviated as STM). Here "decisions" are made on incoming information as to whether it has importance or an association with any other information which has been previously stored. Unimportant items are selectively forgotten or ignored (e.g. the ticking of a clock in the background) while other items can be processed for storage with other previously learned information or as new units of information. The function of STM is to: discriminate between incoming items, test and compare them to other units of information, create symbols or labels, and to send units on for storage (a similar process to filing papers in a cabinet), In summary, the STM system chooses items of import, sorts and classifies, reduces the information into concentrated units for storage, then labels it for retrieval. This process is called encoding and labelling.

The final step in the process is the storage of encoded information into long term memory (abbreviated as LTM). This area can be considered as a component which stores and retains coded information units until they are retrieved by STM for use. Since this portion is basically file storage, the part of the model which is of primary interest is the STM where storage and retrieval is handled.

The most characteristic feature of STM is its capacity. Due to the continuous influx of sensory information which must be handled the maximum amount which can be manipulated at any point in time is 7 units, plus or minus 2. In order to accomodate all of this information the STM recodes data to allow for short term storage. A simplified example may help to explain this. If a person tries to remember 7 separate numbers for immediate use (not to be remembered) he would be utilizing most of the STM store available to him. If an interruption occurs forcing his attention to be diverted (this would utilize STM space) then some of the numbers may be lost. This happens when a phone number is looked up in the directory, then some distraction occurs and when we start to dial the number we find that we only remember a portion or we may be unsure of it. If, however, those seven numbers can be mentally combined and labelled as say "John's phone number", the STM space requirement is only 1, allowing 6 more units for immediate use. This occurs when we look a number up in the directory and carry on performing other tasks while correctly dialing the number.

Since this capacity is finite, individual decisions are continually made as to the fate of units of information. Some pieces are forgotten deliberately, such as a one time phone number, or if the information is important to the individual then the unit is transfered to LTM, such as our own phone number. Because of the coding system, the label referring to "our own phone number" produces immediate retrieval of that particular unit from LTM.

The amount of information continually being stored and retrieved presents the individual with certain problems: information improperly labeled may not be retrieved at an appropriate time, if at all; important information may be discarded if it is inadvertantly determined unimportant; too much information may be coming at one time resulting in confusion; and interference can be caused by some previous learning situation or any of a variety of external causes such as an emotional problem.

PROBLEM SOLVING

In order for information to be more useful to a person it must be learned (i.e. labelled and stored in LTM) in more than a rote fashion. Retrieval procedures must be also learned to allow information to be functional even when the situation format varies from the original learning situation. For simplicity we will use an example from mathematics: students learn an algorithm for a problem and then do a series of worksheets for practice. Eventually they are given a word problem with the same type of problem embedded in a situational dilemma; hopefully, they can identify the appropriate key items and retrieve from LTM the correct algorithm to solve the problem. By using this example, it can be seen that problems range generally from simple straight forward recall to embedded situational dilemmas requiring identification of key components. It also becomes apparent that a vital factor in problem solving is the appropriate retrieval of factual information. If we consider the LTM as a kind of filing system, the next obvious consideration is HOW that information was labelled and filed originally (i.e., encoding and labelling done by

STM).

Considerable work has been done on the development of problem solving abilities in individuals as they learn to play chess. First; there is the novice, who has little or no intelligent self regulation and plays one move at a time usually in a confused state. Next, as the player becomes more familiar with the rules and subprocesses there is an increase in his deliberate self-regulation and he starts to anticipate moves. The expert player has the subprocesses of the game learned to a point of overlearning and reacts to a move in a automatic way, this allows greater concentration and advanced anticipation of his opponents moves. Basically, the individual has learned HOW to label and store game information so that when retrieval is necessary it is automatic. This allows his STM more freedom to "think of other things", such as anticipating an opponents moves. The novice learning state is seen in circumstances where the individual is confronted with new or unusual situations or information. There is a period of time where confusion occurs: information may be misidentified as important; perhaps poor labeling techniques are used; there may be a resort to some technique which was successful elsewhere but may be inappropriate in this new situation. Learning occurs through a trial and error means. Eventually, the individual finds some system for processing the information, at this point he begins to advance and can finally start some manipulation of the newly stored data. Again, manipulation can only occur when there is a functional, retrievable knowledge base. This in turn is dependent on the original manner in which the STM processed that incoming data.

HUMAN DEVELOPMENT

While the work in Human Development reflects a variety of theoretical positions (from Stimulus-Response to Gestalt), they all recognise a successive build-up of complex levels based on a firm knowledge base. This primary knowledge base is the result of two interactive factors: capacity (i.e. memory) and strategies (i.e., processing invovled in storage and retrieval). The STM capacity starts off at approximately 5 units in a child, with adults in unfamiliar stimulus situations (a novice state) working at the same capacity level as children. Since the development of students occurs in stages and there is such a difference in the amount and type of data that a student can learn, how can we account for this, considering that the capacity is fairly stable across people in general? It is felt that the differences between students within a level or stage rests upon the ability to effectively group or chunk information for storage in LTM. The strategies or processes necessary to encode this information appear to occur naturally but on an individual time frame. Some authors feel that the quality of the processing is much more important than the capacity in the development of that primary knowledge base.

Question:

If we know that the key to buiding a knowledge base is the processing, given a stable capacity, is it possible to teach a student HOW to process, based on Information Processing, unfamiliar information (i.e., science) rather than having him find out for himself? This is the basis for the present study.

ASSIGNMENT RECORD

The following sheet is for recording the completeness of assignments. This is only to document the amount of work attempted and is not meant for grading purposes. Please use a decimal system to indicate the questions attempted; for example, if 5 questions have been assigned and 3 and a half were completed, then mark 3.5 in the appropriate space. In the case of Summarizing a Reading, if the assignment is complete a checkmark will suffice, otherwise estimate the amount done.

PART III. INFORMATION GIVEN ONLY TO THE COMPARISON TEACHERS

HEAT OUTLINE

TIME: 2 PERIODS

CHAPTER 1 What is Energy?

1-1 Why Study Energy?

1-2 Energy and Its Forms

Page 6, questions 1,3.

1-4 Energy Transformations

1-5 Potential and Kinetic Energy

Page 14, questions 1,2. Page 16, questions 1,2,5,7.

1-3 Investigation: Using Various Forms of Energy

Demonstration - Procedures: Part 1,3,4,6,7. Parts 2 and 5 discussion. Answer all italicized questions under each part as well as page 13, questions 1-4.

TIME: 3 PERIODS

CHAPTER 2 Forces

1-7 What is a Force?

Page 20, question 1.

1-9 The Force of Gravity on a Mass

Page 24, questions 1-4.

1-11 What Causes Friction?

Page 35, questions 1,2a, 3a and b, 4a and b.

1-8 Investigation: Measuring Forces

Answer all italicized questions.Page 22, questions 1 and 2.

1-10 Investigation: What is Friction?

Procedures: Part 1 (include D), Part 2, Part 3 and Part 4. Answer all italicized questions under each part. Page 27-28, questions 1,3,4,7,11.

TIME: 2 PERIODS

CHAPTER 3 Work: A Measure of Energy

1-13 Measuring Energy

Page 40, questions 1,3,5a,b and c.

1-14 Investigation: Calculating Work and Energy

Procedures: A through I. Answer all italicized questions. Pages 43-44, questions 1,5,10,11.

TIME: 3 PERIODS

CHAPTER 4 Simple Machines

1-16 What is a Simple Machine?

Page 48, questions 1 and 2

1-19 Common Simple Machines

Page 66, question 1 (including starred sentences).

1-17 Investigation: Pulleys

Procedures: Part 1,2,3 (omit 4 and 5). Answer all italicized questions. Page 51, questions 1,2,4.

1-18 Investigation: Levers and Screws

Procedures: Part 1,2,3. Answer all italicized questions. Page 57, questions 1 and 5.

TEST

TIME: 2 PERIODS

CHAPTER 5 Factors That Determine a Change in Motion

1-22 Accelerating and Decelerating

Page 72, question 1.

1-25 The Importance of Inertia

Page 80, question 1.

1-23 Investigation: Balanced and Unbalanced Forces

Procedure: A-F (omit G). Answer all italicized questions. Page 74, questions 1a,b,c and 2a,b,c.

1-24 Investigation: Observing Inertia

Procedure: A,B and D (omit C). Answer all italicized questions. Page 77, questions 3a,b,c and 6a,b,c,d.

TIME: 3 PERIODS

CHAPTER 6 The Law of Conservation of Energy and Energy Converters

1-28 The Law of Conservation of Energy

Page 85, question 1.

1-31 The Power of an Energy Converter

Page 96, question 1 and 2.

1-29 Investigation: Energy Converters

Procedure: Part 1 Demonstration A-F (omit E), include the concept of efficiency but not the formula. Answer all italicized questions. Part 2 - G. Page 89, questions 1,2,5,11,12.

1-32 Investigation: Measuring your own Power

Procedure: Parts A-I. Page 97-98, questions 1,4,5.

TIME: 3 PERIOD

CHAPTER 7 Heat Energy

1-34 Heat Energy and Energy Transforations

Page 104, question 1.

1-36 The Energy of Particles

Page 109, question 1.

CHAPTER 9 The Transfer of Heat Energy

1-47 What Happens to Heat Energy

Page 141, question 7.

1-48 Investigation: Conduction

Demonstration. Procedure: Part 1 A-G (omit Part 2). Page 146, questions 2a,b,c,d; 3a,b; 7a,b,c; 13a,b.

1-49 Investigation: Convection

Demonstration. Part 1 A-C (discuss Part 2). Page 151, questions 3a,b; 4; 8a,b,c.

*1-50 Investigation: Radiation of Infra-red Rays

Discuss concepts.

Page 157, questions 3a,b and 12a-f.

1-51 What Happens When Heat Energy Is Transferred

Page 162, questions 1 and 2.

1-52 Infra-Red Radiation

Page 166, question 1a-d.

1-53 Insulation

Page 169-170, questions 1,6,9.

ASSIGNMENT RECORD

The following sheet is for recording the completeness of assignments. This is only to document the amount of work attempted and is not meant for grading purposes. Please use a decimal system to indicate the questions attempted; for example, if 5 questions have been assigned and 3 and a half were completed, then mark 3.5 in the appropriate space.

APPENDIX B

PRETEST

Select the letter of the statement or phrase which BEST answers the question. Place your response on the answer sheet provided. DO NOT write on this booklet.

1. Machines
   A. let you exert less force
   B. let you exert a force in an easier direction
   C. do not decrease the amount of energy you have to use
   D. all of the above
2. When you supply energy faster than friction can transform the mechanical energy to heat energy this is known as
   A. deceleration
   B. inertia
   C. acceleration
   D. a balanced force
3. A vacuum bottle is used to maintain the temperature of foods and drinks. Air between the walls of the bottle is removed because air
   A. transfers heat energy
   B. evaporates heat energy
   C. produces heat energy
   D. eliminates heat energy
4. Given the following combinations of simple machines; which best represents a wheelbarrow?
   A. lever and screw
   B. lever and a wheel and axle
   C. inclined plane and a screw
   D. inclined plane and a wheel and axle
5. After you stop pedaling your bicycle, it runs for awhile and then stops because
   A. gravity stops it
   B. the potential energy is used up
   C. inertia stops it
   D. inertia keeps it going, friction stops it
6. Air does not freeze to a solid at room temperature because
   A. the individual particles of air have nothing else to give their mechanical energy to
   B. there is too much friction between individual air particles
   C. it is impossible to slow down individual particles
   D. the mechanical energy of the individual particles is constantly converted to heat energy
7. Heat transfer through a vacuum can be accomplished by
   A. convection
   B. radiation
   C. conduction
   D. diffusion

8. Which of the following are examples of forces acting?
   X: a footballer kicking a ball
   Y: a goalkeeper stopping a ball
   Z: a referee blowing his whistle
   A. X and Z only
   B. X and Y only
   C. Y and Z only
   D. X,Y and Z
9. Potential energy is:
   A. lost if you don't keep supplying it to the system
   B. the same as kinetic energy
   C. can be stored for as long as you want
   D. part of the kinetic energy
10. In a laboratory you lift a 10 N rock 2 metres in 10 seconds. How much work have you done?
   A. 200 J
   B. 100 J
   C. 20 J
   D. 10 J
11. A man weighing 1 000 N possesses 8 000 J of potential energy. How high is the man above ground level?
   A. 8 000 m
   B. 800 m
   C. 80 m
   D. 8 m
12. The force of attraction between matter is called
   A. inertia
   B. gravity
   C. elastiscity
   D. friction
13. The kind of energy produced by a hot glowing object is
   A. electrical
   B. chemical
   C. mechanical
   D. radiant
14. Mass
   A. varies as does the gravitational pull on a body
   B. is the same as the weight of a body
   C. is constant for a body
   D. none of these
15. An example of a body containing kinetic energy is
   A. a ball thrown upward, at the top of its path
   B. an unexploded stick of dynamite
   C. both of these
   D. neither of these
16. Convection is most likely to occur in
   A. ice
   B. steel
   C. wood
   D. water

17. The blast-off of a rocket entails the following conversion of energy
    - A. Potential energy converted to kinetic energy
    - B. chemical energy converted to mechanical energy
    - C. chemical energy converted to heat energy
    - D. all of the above
18. According to the Law of Conservation of Energy, the amount of energy in the universe .
    - A. decreases as it is converted
    - B. never varies in form
    - C. remains constant but can be converted
    - D. increases as it is converted
19. A spring scale is used to measure
    - A. force
    - B. size
    - C. friction
    - D. work
20. How much work is done when a load of 12 N is raised 2 metres?
    - A. 24 Joules
    - B. 24 Newtons
    - C. 6 Joules
    - D. 6 Newtons
21. The work put into a machine
    - A. equals the work put out by the machine
    - B. is increased by the machine
    - C. is more than put out by the machine
    - D. all of the above, depending on the efficiency of the machine
22. When ice melts in a glass of water
    - A. heat flows from the ice to the water
    - B. heat flows from the water to the ice
    - C. cold flows from the ice to the water
    - D. heat enters the ice as cold comes out
23. A unit of power of one newton metre per second is known as a
    - A. kilowatt
    - B. horsepower
    - C. watt
    - D. joule
24. Which of the following will NOT decrease the amount of friction between two bodies?
    - A. lubrication
    - B. decreasing the area of contact
    - C. decreasing the mass of both bodies
    - D. none of these

25. If a body is moving in a straight line with a constant speed, which of the following statement MUST BE FALSE?
    A. there are no forces acting on the body
    B. there may be forces acting on the body but then cancel each other out
    C. there is a force at right angles to its path
    D. there is no frictional force
26. Power is defined as
    A. work
    B. rate of doing work
    C. the rate energy is created
    D. a force acting through a distance
27. The ratio of work done by a machine to the work put into it is called the
    A. efficiency
    B. acceleration
    C. power
    D. force
28. The force that most often opposes the uniform motion of a body is
    A. friction
    B. inertia
    C. gravity
    D. pressure
29. Newton's First Law says that the velocity of a body unless acted upon by a/an .
    A. accelerates; balanced force
    B. remains constant; unbalanced force
    C. accelerates; unbalanced force
    D. remains constant; balanced force
30. A simple pulley is used to raise a flag. The flag weighs 2.5 kg. and will be raised 30 metres. You must
    A. exert an effort of 2.5 kg.
    B. exert an effort through 30 metres
    C. use a single fixed pulley
    D. do all of the above
31. Energy is the
    A. amount of work done
    B. ability to apply pressure
    C. ability to do work
    D. amount of work needed to be done
32. Which is the best insulator?
    A. a poor conduction material
    B. a good conduction material
    C. a liquid, such as water
    D. a material with densely packed particles

33. To obtain balanced forces (no change in motion) the two forces acting on a body must be
    A. equal in the same direction
    B. unequal in the same direction
    C. equal in strength and opposite in direction
    D. unequal and opposite
34. That part of the energy of a body which the body possesses as a result of its motion is known as
    A. potential energy
    B. kinetic energy
    C. inertia
    D. force
35. Temperature is determined by
    A. the energy of the motion of particles
    B. momentum of molecules
    C. potential energy of molecules
    D. heat
36. Heat conduction is likely to be greatest in a substance in which molecules are
    A. packed tightly together
    B. packed loosely together
    C. at rest
    D. absent
37. In the engine of an automobile going along the highway, the changes in energy are
    A. heat to mechanical to motion
    B. chemical to heat to mechanical to motion
    C. chemical to magnetic to heat to motion
    D. chemical to heat to motion
38. Bill sits 1 metre from the fulcrum of the teeter-totter, he does NOT balance Jim who is on the other end and 2 metres from the fulcrum. If Bill wants to just balance Jim, he should
    A. move closer to the fulcrum
    B. tell Jim to move closer to the fulcrum
    C. move away from the fulcrum
    D. cannot tell from the information given
39. How does a decrease in mass affect the motion of a body if the force is kept constant?
    A. the body will accelerate faster
    B. the body will accelerate slower
    C. the body will accelerate at the same rate
    D. all of the above depending on how much of a decrease in mass

40. A certain machine is said to be 75% efficient. What does this mean?
    A. the machine operates with no energy loss 75% of the time
    B. only 75% of the work put into the machine is returned as useful energy
    C. only 75% of the energy put into the machine is converted
    D. only 75% of the work put into the machine can be measured as energy
41. Which is NOT an example of force?
    A. a magnet pulling an iron nail toward it
    B. a pencil rolling across the desk
    C. an astronaut floating in a weightless state
    D. none of the above
42. Which is NOT an example of a change from mechanical energy to heat energy?
    A. striking a nail with a hammer
    B. putting brakes on to stop a car
    C. wood burning in a fireplace
    D. a meteorite burning up as it enters the earth's atmosphere
43. There are 3 cylinders on the demonstration table. Each one is filled with either air, water or oil. A steel ball bearing takes 1 second to fall through the cylinder with air; 2 seconds to fall through the cylinder with water; and, 20 seconds to fall through the cylinder with oil. This shows that
    A. the force of gravity is greatest in air
    B. the force of gravity is greatest in oil
    C. the force of friction is greatest in water
    D. the force of friction is greatest in oil
44. The invention of a machine which would never require an intake of energy once it got going, but would continue to function
    A. is impossible according to the Law of Conservation of Energy
    B. is possible according to the Law of Conservation of Energy
    C. deals with Newton's First Law of Motion
    D. is possible providing the energy converter adheres to Newton's First Law of Motion

UNIT TEST

Select the letter of the statement or phrase which BEST answers the question. Place your response on the answer sheet provided. DO NOT write on this booklet.

1. Temperature is determined by
   A. the energy of the motion of particles
   B. momentum of molecules
   C. potential energy of molecules
   D. heat
2. In a laboratory you lift a 10 N rock 2 metres in 10 seconds. How much work have you done?
   A. 200 J
   B. 100 J
   C. 20 J
   D. 10 J
3. Which is the best insulator?
   A. a poor conduction material
   B. a good conduction material
   C. a liquid, such as water
   D. a material with densely packed particles
4. The kind of energy produced by a hot glowing object is
   A. electrical
   B. chemical
   C. mechanical
   D. radiant
5. Mass
   A. varies as does the gravitational pull on a body
   B. is the same as the weight of a body
   C. is constant for a body
   D. none of these
6. The work put into a machine
   A. equals the work put out by the machine
   B. is increased by the machine
   C. is more than put out by the machine
   D. all of the above, depending on the efficiency of the machine
7. Energy is the
   A. amount of work done
   B. ability to apply pressure
   C. ability to do work
   D. amount of work needed to be done
8. An example of a body containing kinetic energy is
   A. a ball thrown upward, at the top of its path
   B. an unexploded stick of dynamite
   C. both of these
   D. neither of these

9. Machines
    A. may let you exert less force
    B. may let you exert a force in an easier direction
    C. do not decrease the amount of energy you have to use
    D. all of the above
10. According to the Law of Conservation of Energy, the amount of energy in the universe .
    A. decreases as it is converted
    B. never varies in form
    C. remains constant but can be converted
    D. increases as it is converted
11. Given the following combinations of simple machines; which best represents a wheelbarrow?
    A. lever and screw
    B. lever and a wheel and axle
    C. inclined plane and a screw
    D. inclined plane and a wheel and axle
12. How much work is done when a load of 12 N is raised 2 metres?
    A. 24 Joules
    B. 24 Newtons
    C. 6 Joules
    D. 6 Newtons
13. Heat transfer through a vacuum can be accomplished by
    A. convection
    B. radiation
    C. conduction
    D. diffusion
14. When you supply energy faster than friction can transform the mechanical energy to heat energy this is known as
    A. deceleration
    B. inertia
    C. acceleration
    D. a balanced force
15. Which is NOT an example of force?
    A. a magnet pulling an iron nail toward it
    B. a pencil rolling across the desk
    C. an astronaut floating in a weightless state
    D. none of the above
16. To obtain balanced forces (no change in motion) the two forces acting on a body must be
    A. equal in the same direction
    B. unequal in the same direction
    C. equal in strength and opposite in direction
    D. unequal and opposite

17. Bill sits 1 metre from the fulcrum of the teeter-totter, he does NOT balance Jim who is on the other end and 2 metres from the fulcrum. If Bill wants to just balance Jim, he should
    A. move closer to the fulcrum
    B. tell Jim to move closer to the fulcrum
    C. move away from the fulcrum
    D. cannot tell from the information given
18. A man weighing 1 000 N possesses 8 000 J of potential energy. How high is the man above ground level?
    A. 8 000 m
    B. 800 m
    C. 80 m
    D. 8 m
19. A vacuum bottle is used to maintain the temperature of foods and drinks. Air between the walls of the bottle is removed because air
    A. transfers heat energy
    B. evaporates heat energy
    C. produces heat energy
    D. eliminates heat energy
20. A certain machine is said to be 75% efficient. What does this mean?
    A. the machine operates with no energy loss 75% of the time
    B. only 75% of the work put into the machine is returned as useful energy
    C. only 75% of the energy put into the machine is converted
    D. only 75% of the work put into the machine can be measured as energy
21. Which of the following are examples of forces acting?
    X: a footballer kicking a ball
    Y: a goalkeeper stopping a ball
    Z: a referee blowing his whistle
    A. X and Z only
    B. X and Y only
    C. Y and Z only
    D. X,Y and Z
22. The invention of a machine which would never require an intake of energy once it got going, but would continue to function
    A. is impossible according to the Law of Conservation of Energy
    B. is possible according to the Law of Conservation of Energy
    C. deals with Newton's First Law of Motion
    D. is possible providing the energy converter adheres to Newton's First Law of Motion

23. The force of attraction between matter is called
    A. inertia
    B. gravity
    C. elastiscity
    D. friction
24. Newton's First Law says that the velocity of a body unless acted upon by a/an .
    A. accelerates; balanced force
    B. remains constant; unbalanced force
    C. accelerates; unbalanced force
    D. remains constant; balanced force
25. Which is NOT an example of a change from mechanical energy to heat energy?
    A. stricking a nail with a hammer
    B. putting brakes on to stop a car
    C. wood burning in a fireplace
    D. a meteorite burning up as it enters the earth's atmosphere
26. That part of the energy of a body which the body possesses as a result of its motion is known as
    A. potential energy
    B. kinetic energy
    C. inertia
    D. force
27. After you stop pedaling your bicycle on a flat road, it runs for awhile and then stops because
    A. gravity stops it
    B. the potential energy is used up
    C. inertia stops it
    D. inertia keeps it going, friction stops it
28. A spring scale is used to measure
    A. force
    B. size
    C. friction
    D. work
29. When ice melts in a glass of water
    A. heat flows from the ice to the water
    B. heat flows from the water to the ice
    C. cold flows from the ice to the water
    D. heat enters the ice as cold comes out
30. There are 3 cylinders on the demonstration table. Each one is filled with either air, water or oil. A steel ball bearing takes 1 second to fall through the cylinder with air; 2 seconds to fall through the cylinder with water; and, 20 seconds to fall through the cylinder with oil. This shows that
    A. the force of gravity is greatest in air
    B. the force of gravity is greatest in oil
    C. the force of friction is greatest in water
    D. the force of friction is greatest in oil
31. How does a decrease in mass affect the motion of a body if the force is kept constant?
    A. the body will accelerate faster
    B. the body will accelerate slower

C. the body will accelerate at the same rate
D. all of the above depending on how much of a decrease in mass

32. Air does not freeze to a solid at room temperature because
A. the individual particles of air have nothing else to give their mechanical energy to
B. there is too much friction between individual air particles
C. it is impossible to slow down individual particles
D. the mechanical energy of the individual particles is constantly converted to heat energy

33. A unit of power of one newton metre per second is known as a
A. kilowatt
B. horsepower
C. watt
D. joule

34. In the engine of an automobile going along the highway, the changes in energy are
A. heat to mechanical to motion
B. chemical to heat to mechanical to motion
C. chemical to magnetic to heat to motion
D. chemical to heat to motion

35. Convection is most likely to occur in
A. ice
B. steel
C. wood
D. water

36. The force that most often opposes the uniform motion of a body is
A. friction
B. inertia
C. gravity
D. pressure

37. Potential energy is:
A. lost if you don't keep supplying it to the system
B. the same as kinetic energy
C. can be stored for as long as you want
D. part of the kinetic energy

38. Heat conduction is likely to be greatest in a substance in which molecules are
A. packed tightly together
B. packed loosely together
C. at rest
D. absent

39. If a body is moving in a straight line with a constant speed, which of the following statement MUST BE FALSE?
A. there are no forces acting on the body
B. there may be forces acting on the body but then cancel each other out
C. there is a force at right angles to its path
D. there is no frictional force

40. Which of the following will NOT decrease the amount of

friction between two bodies?
A. lubrication
B. decreasing the area of contact
C. decreasing the mass of both bodies
D. none of these

41. A simple pulley is used to raise a flag. The flag weighs 2.5 kg. and will be raised 30 metres. You must
A. exert an effort of 2.5 kg.
B. exert an effort through 30 metres
C. use a single fixed pulley
D. do all of the above

42. The ratio of work done by a machine to the work put into it is called the
A. efficiency
B. acceleration
C. power
D. force

43. Power is defined as
A. work
B. rate of doing work
C. the rate energy is created
D. a force acting through a distance

44. The blast-off of a rocket entails the following conversion of energy
A. Potential energy converted to kinetic energy
B. chemical energy converted to mechanical energy
C. chemical energy converted to heat energy
D. all of the above

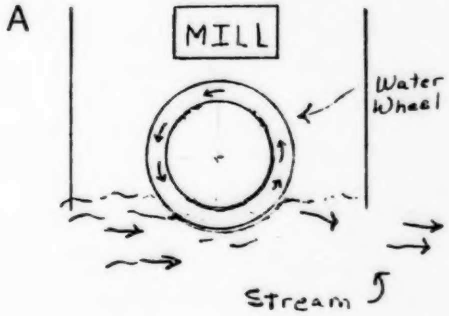
ESSAY QUESTIONS

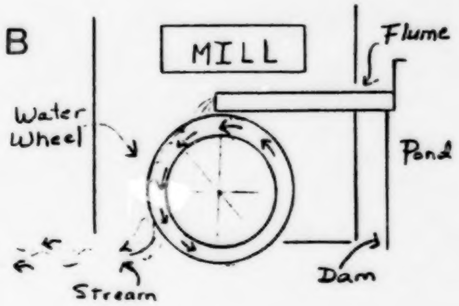
Answer each question in as much detail as possible. Use the back of the sheet if you need more room.

1. Even if you have a good fire going in a fireplace, explain why your back still feels cold when you stand facing it.

2. Explain why a match catches on fire and then burns when the head is rubbed over a particular surface.

3. The following two diagrams are of mills used for hundreds of years to run grain grinders and saw mills. Diagram A. shows an undershot water wheel, where the paddle portion sits in the river and is turned as the water flows by. Diagram B. shows an overshot water wheel. A dam is built across a stream and the water is led through a wooden or metal flume to the top of the wheel. The wheel turns as water flows over the wheel and forms a stream below. Which water wheel is more efficient? Explain why the one you have chosen is more efficient than the other.


A
MILL
Water Wheel
Stream


B
MILL
Flume
Water Wheel
Pond
Dam
Stream